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[*From the* Quarterly Journal *of the* Geological Society, *for November* 1863.]

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FURTHER OBSERVATIONS

ON THE

DEVONIAN PLANTS OF MAINE, GASPÉ,

AND

NEW YORK.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

BY

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[PLATES XVII.–XIX.]

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§ I. *Introduction.*

SINCE the preparation of my paper "On the Devonian Flora of North-eastern America," published last year*, I have been enabled to explore more thoroughly than heretofore the plant-bearing beds at Perry, in Maine; and Mr. R. Bell, of the Geological Survey of Canada, has collected some interesting specimens from the Gaspé sandstones, which have been kindly placed in my hands by Sir W. E. Logan for determination. Some important facts have also been ascertained respecting the distribution of the Devonian rocks of the State of New York, which give to several of the Plants from that region a somewhat older geological position than that assigned to them in my former paper. These supplementary facts I now propose shortly to state.

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* Quart. Journ. Geol. Soc. vol. xviii. p. 296.

§ II. *Perry, Maine.*

With respect to the geological relations of the rocks at this place, I have little to add to the descriptions of Professor Hitchcock, referred to in my former paper. The beds at Pigeon Hill and its vicinity, referred by him to the Upper Silurian, consist of hard, grey and reddish shale and sandstone, overlain by trappean or trap-ash beds, and traversed by trap-dykes. They are somewhat, but very unequally, hardened and altered, and are inclined at high angles, with prevailing dips to the north-east. They contain abundance of *Lingulæ*, and of small Lamellibranchiate Shells which have been referred to the genus *Modiolopsis*. Mr. Billings regards the *Lingula* as an undescribed species, and it appears to differ from that found at St. John. I think it quite possible, however, that these beds at Perry may be the equivalents of the St. John slates; and from their relation to other beds at Pembroke which contain fossils of Lower Helderberg age, and identical in many species with my "Arisaig group" in Nova Scotia, I cannot doubt that they are of Upper Silurian date, unless indeed they may be Lower Devonian.

Upon these beds repose, in an unconformable manner, the Devonian red conglomerates. In their lower part they contain thick beds of coarse breccia, containing angular fragments of the harder members of the underlying series, sometimes 3 feet in length. These beds are well seen at the mouth of the Little River of Perry, near Point Pleasant. Above these are red conglomerates, with rounded pebbles of quartzite, syenite, and other hard rocks. The pebbles are of moderate size; and there are interstratified beds of bright red sandstone, with green spots and stains, and occasional thin grey layers. The thickness of these beds exposed on the south side of Little River is about 1300 feet. They are probably the equivalents of the upper part of the St. John series and the Upper Red Sandstones of Gaspé; and it is worthy of note, as suggesting a caution to explorers of those regions, that these rocks strikingly resemble in their mineral character the Lower Carboniferous red sandstones and conglomerates of some parts of Nova Scotia and New Brunswick, and also the probably Mesozoic "New Red Sandstones" of these provinces.

The fossil Plants occur most abundantly in a layer of grey sandstone, about 2 feet thick, and apparently of small horizontal extent, in the upper part of the red conglomerate. This little bed is filled with fragments of Plants, and probably occupies a spot where a stream running from neighbouring land emptied itself into the sea. It is rather a portion of the red sandstone bleached by the deoxidizing and solvent action of the vegetable matter, than a distinct bed; and the same remark applies to the numerous grey spots and thin layers in other parts of the series. A very pretty illustration of this occurs in a bright-red, fine-grained sandstone farther up the Little River, in which Mr. Jethro Brown, of Perry, has found fronds of *Cyclopteris Jacksoni*, and branches of *Psilophyton*, which have im-

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printed themselves in light-greenish stains on the red stone. The Plants have been drifted, and are for the most part in fragments, the smaller and more delicate of which occur in the upper part of the bed, and those of larger size in its lower part. Above and below the Plant-bearing bed are red sandstones, passing into the usual red conglomerate. Though there are abundant exposures of the red sandstone and conglomerate on the coast of Perry, I could not learn that fossils have been found in any other locality than those abovementioned, so that their occurrence must be considered rare. In the underlying Upper Silurian Series I could find no Plants, except some obscure fragments of slender stems.

With the assistance of Mr. Brown, I was enabled to obtain a number of specimens from the original Plant-bearing bed, the actual exposure of which we indeed worked out. The more important of these I shall now notice in detail.

1. Coniferous wood (Dadoxylon et Aporoxylon).

Among the most abundant fossils at Perry are fragments of stems and roots, and strips of bark, belonging to two or more species of coniferous trees. They are pyritized, so that their structures can be made out only as opaque objects, or after treatment with nitric acid. In the specimens formerly collected, I was able to observe only a porous woody tissue (*Aporoxylon*). Some of my present specimens, however, show three or four rows of discs on the cell-walls, and are not distinguishable from *Dadoxylon Ouangondianum* of St. John, though they are not in a sufficiently good state of preservation to admit of satisfactory comparison. Some of the flattened stems show marks of lateral branches or cones at rare intervals (Pl. XVIII. fig. 20); others are long, slender, and tortuous, and were probably roots (Pl. XVII. fig. 5).

Among the specimens collected by Mr. Brown is one with a porous tissue, in the form of a flattened stem or branch, 2 inches in diameter, and with a pith half an inch in diameter (not of the Sternbergia-type). The structure of the wood closely resembles that of *Aporoxylon primigenium*, Unger.

2. Stigmaria pusilla, spec. nov. Pl. XVII. fig. 3.

Allied to S. exigua, *but with larger and more distant scars, not in depressed areoles.*

A few fragments of the bark of this species were found scattered over the surface of a slab at Perry. It is of the same slender type as *Stigmaria exigua*, of the Chemung group of New York, but is sufficiently different to warrant the belief that it was the root of a distinct species of *Sigillaria*.

3. Cyperites.

Two kinds of leaves, resembling those of *Sigillaria*, occur at Perry. They are a line or less in breadth and 3 inches or more in length, and have respectively two and four well-marked ribs. Though no trunks of *Sigillaria* have been found, I regard these leaves and the *Stigmaria* above described as evidence of the existence of two species of that genus.

4. ANARTHROCANNA PERRYANA, spec. nov. Pl. XVIII. fig. 21.

Stem cylindrical, swelling slightly at the nodes; ribs flattened, about fourteen in the circumference of a stem three-fourths of an inch in diameter; ribs at the nodes apparently continuous with the decurrent verticillate (?) *petioles or branchlets.*

This curious stem at first sight resembles a *Calamites*; but it has no distinct articulation, and the ribs appear to separate from the stem and to pass into the decurrent and probably verticillate branchlets or petioles, which are given off at an acute angle, and bear traces of slender leaves, which are, however, too imperfect for description. The plant corresponds sufficiently, I think, with the characters of Gœppert's genus *Anarthrocanna* to be included in it. It was probably allied to *Calamites* or *Asterophyllites*; and possibly the species next mentioned may be the fruit of this Plant, though I have not seen them in connexion.

5. CARPOLITHES SPICATUS, spec. nov. Pl. XVII. fig. 15.

Carpels or spore-cases: oval, about a line in length, apparently with a thick outer coat; densely placed on a thick rachis.

This is evidently a spike of fructification, and may be allied to *Trigonocarpum racemosum*, described in my former paper. It more nearly resembles the fructification of *Annularia* and *Sphenophyllum* than any other fossil fruits known to me. Its parts are too indistinct to admit of minute description, and the two-ranked appearance of the seeds or fruits is probably deceptive, as there are indications that the specimen is a cylindrical spike flattened.

6. LYCOPODITES RICHARDSONI, spec. nov. Pl. XVII. figs. 1 & 2.

Stem slender, tortuous, dichotomous; barren branches with short erect or recurved leaves, apparently in two ranks; fertile branches lateral, one-sided, in the form of sessile strobiles. These strobiles are the Lepidostrobus Richardsoni *of my former papers.*

Under the name quoted in the above description, I described in a former paper* a very singular specimen collected at Perry by Mr. Richardson, and which, though at first sight it resembled a pinnate leaf, I believed to be a cone of the nature of *Lepidostrobus*. More perfect specimens confirm this view, and show that these cones were sessile on one side of a slender and probably creeping stem, terminating in dichotomous branches having short, stout, slightly recurved leaves, apparently in two rows. The generic name of *Lepidostrobus* being no longer applicable, I propose to place the Plant in *Lycopodites*, a genus no doubt at present somewhat unsettled, but in which this Plant, at least, fairly deserves a place.

7. PSILOPHYTON.

Fragments referable to this genus are very abundant at Perry, but all in a very imperfect state. I believe that I can recognize representatives of the three species which I have named respectively *P. princeps*, *P. elegans*, and *P. glabrum*, but cannot be quite certain of this. Here, as elsewhere, I should have been ready to refer these Plants to the convenient category of Fucoids, but for my knowledge of their forms and structures obtained in Gaspé.

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* Canadian Naturalist, vol. vi. p. 174.

8. LEPTOPHLŒUM RHOMBICUM, Dawson. Pl. XVIII. fig. 19.

Additional specimens of this Plant have enabled me to ascertain that its branches bifurcated regularly, in the manner of *Lepidodendron*, and tapered somewhat rapidly; that its leaves were long, parallel-sided, and one-nerved; and that it produced strobile-like bodies with narrow-pointed, closely appressed scales borne on the sides of the branches. I have attempted to give a restoration of the Plant, from several specimens in my possession, in Pl. XVIII. fig. 19. The other characters of the genus, and the points in which it differs from *Lepidodendron* and *Ulodendron*, are stated in my former paper.

9. LYCOPODITES COMOSUS, spec. nov. Pl. XVII. fig. 14.

Stem short, not observed to branch, densely covered with long filiform leaves.

This little Plant, of which several specimens, all equally diminutive, were found, somewhat resembles *Selaginites Erdmanni* of Germar, but is smaller and differently proportioned.

10. CORDAÏTES (PYCHNOPHYLLUM) FLEXUOSUS, spec. nov. Pl. XVII. fig. 9.

Leaves lanceolate, acuminate, broad at the base; nerves numerous, parallel, somewhat sinuous and uneven.

A number of more or less perfect specimens of this leaf were found. It has the general appearance of the leaves of *Cordaïtes*; but less distinct venation, and apparently less rigidity than the other species. I place it in this genus merely provisionally, as its true affinities are, of course, quite uncertain.

11. CYCLOPTERIS JACKSONI, Dawson. Pl. XIX. fig. 26.

This is by far the most abundant species at Perry, and a large number of specimens were obtained. One of these shows that the full-grown frond was a foot in length, with a strong woody rugose petiole a quarter of an inch thick at the base. Some of these petioles in a pyritized state show traces of scalariform vessels. Old stipes deprived of their leaves very closely resemble the *Rhachiopteris pinnata* of the Marcellus shale of New York, though not quite so large, and perhaps more rugose. Among the numerous scattered pinnæ of this species there are some of much smaller size than the others, which may possibly indicate a distinct species; but, for the present, I am rather disposed to regard them as merely a variety. (See Pl. XIX. fig. 26, *c*.)

I also found a few detached pinnules, which I believe to belong to *Cyclopteris Halliana*, of the Chemung group of New York. I have attempted to represent the characteristic forms of the ordinary variebetween the pinnules of the upper part, but is less leafy than that of *C. Halliana.*

12. Cyclopteris Rogersi, spec. nov. Pl. XVII. figs. 17, 18; and Pl. XIX. fig. 27.

Habit of growth resembling that of Cyclopteris Jacksoni, *but the pinnules are more elongated and almost cuneate in form, also less densely placed, and with veins more nearly parallel. Stipe stout, woody, furrowed longitudinally, and marked with strong transverse bars or punctures.*

This Fern is less abundant than *C. Jacksoni*, from which the points above mentioned appear sufficient to distinguish it. Its stipe is marked in the manner of *Rhachiopteris punctata* of the Chemung group of New York, and of *C. Roemeriana*, Gœppert, from the Upper Devonian of Europe; of the latter species the present may be regarded as the American representative. I have endeavoured, from the small fragments collected, to give characteristic representations of the appearance of the species. It was probably about the same size as *C. Jacksoni*, but with its stipe not leafy, and its pinnæ and pinnules less densely placed.

It would seem that the remarkable group of pinnate *Cyclopterides*, to which this species belongs, was characteristic of the Upper Devonian throughout North America and Europe. I dedicate the present member of it to Prof. W. B. Rogers, who has done much to direct attention to the deposits of Perry, and has kindly permitted me to use the specimens in his collection.

14. Sphenopteris recurva, spec. nov. Pl. XVII. figs. 7 & 8.

Leaflets small, cuneate, terminating the divisions of a dichotomous winged petiole.

This Plant is represented by small and obscure fragments on the Perry sandstone. Its venation is not preserved; and it may be a small *Cyclopteris* with terminal pinnules, like my *C. Acadica*, from the Lower Coal-formation of Nova Scotia.

15. Trichomanites filicula, spec. nov. Pl. XVII. figs. 12 & 13.

Pinnules slender, attached to long petioles, and bifurcating into slender points.

This species approaches *T. Beinertii* and *T. adnascens*, and there are indications that, like the latter, it may have been parasitic on petioles or branches of other Plants. Numerous specimens occur at Perry, but all are small and somewhat obscure.

16. Filices incertæ sedis. Pl. XVII. figs. 10 & 16.

Among the Plants collected by Mr. Brown are two somewhat obscure examples of the frond or pinnule represented in Pl. XVII. fig. 10. It is of a linear form, with crenations or teeth on the margins. The midrib is delicate; the nerves, which are rather indistinct, appear to be netted near the midrib in the manner of *Glossopteris*, Brongn.; but they are distinct toward the margin, where there are, in the sinuses of the teeth, dark spots, which are probably remains of fructification. These evidences of marginal fructification remove the Plant entirely from *Glossopteris*; and I am not aware of any other

18. Carpolithes? siliqua, spec. nov. Pl. XVII. fig. 4.

Elongate, smooth, flattened, sides slightly sinuate; two inches or less in length; a quarter of an inch or less in breadth.

These objects are too thick and carbonaceous to have been fronds or leaves, and too regular in form to be fragments of stems. They may, however, have been swollen extremities of roots.

§ III. *Gaspé, Canada.*

The Plants collected at Gaspé by Mr. Bell, last summer, consist principally of *Psilophyton princeps* in all states of preservation, still further illustrating the predominance of that species in the Gaspé sandstones, many parts of which were then, for the first time, explored by Mr. Bell. In addition to the facts previously known respecting this Plant, the specimens now obtained illustrate the internal structure of its creeping rhizomes, previously found only flattened or as casts. Mr. Bell has also added to the Gaspé flora *Leptophlœum rhombicum*, previously found only at Perry, and *Didymophyllum reniforme*, a Plant of the Middle Devonian of New York, thus connecting by new links the contemporary floras of these distant localities. His collection also contains two new and curious species of fossil wood, and several fragments possibly indicating new species, but at present of ambiguous character. The more important of these discoveries I indicate under the following heads.

1. Psilophyton princeps, Dawson (rhizomata). Pl. XVIII. fig. 22.

Sir W. S. Logan had obtained from the marine limestones at the base of the Gaspé sandstones, constituting the lowest members of the Devonian Series, if they are not Upper Silurian, a few flattened stems, which in my paper on the Devonian Plants of Gaspé* I referred with doubt to *Psilophyton*. Mr. Bell has collected many additional specimens, some of them perfectly flattened, and which, but for obscure remains of the surface-markings, might readily be mistaken for *Algæ*; others retain more or less perfectly their cylindrical form. The latter are all rhizomata, usually about half an inch in diameter, and retain the structures of the outer bark and internal axis in a calcified state, the cell-walls being changed into coaly matter. The outer bark is seen under the microscope to consist of cellular tissue, dense toward the surface, and more lax within, as seen in a transverse section; while in the longitudinal section the outer portion is found to consist of cells elongated in the manner of bast-tissue, and the inner of ordinary parenchymatous cells. The thick inner bark, which was probably of lax cellular tissue, has disappeared. The slender cylindrical axis consists of woody fibres externally, and of scalariform vessels within; it has a vacant space of very small size in the centre, which may represent a pith, but is perhaps merely a result of decay and shrinking, which have caused the vascular bundle to separate from the woody sheath, and the fibres of the latter to separate in such a manner as to present very different aspects in different parts of the axis of the same rhizome. This structure, it may be observed, corresponds perfectly with that of the aërial stem of the same Plant, illustrated in my paper on the Devonian Plants of Gaspé, the differences being merely those which might have been anticipated from the greater size of the rhizome, and its probably subaquatic or subterranean character. I have endeavoured, in Pl. XVIII. figs. 22*a* to 22*g*, to represent the structures above described, which, with what was previously known, almost complete our knowledge of this interesting Plant.

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* Quart. Journ. Geol. Soc. vol. xv.

It is further interesting to observe that *Psilophyton princeps* has now been found to extend from the very bottom of the Devonian series to its upper members, and throughout every part of Eastern America in which land-plants have been found in these beds. That it has not been recognized in Europe I attribute to its want of decided external characters, when in an imperfect state of preservation, having caused it to be mistaken for Algæ, roots, &c. Similar views might have prevailed here, but for the vast profusion of these Plants found *in situ* in Gaspé, and the admirable preservation both of their external markings and internal structure.

2. NEMATOXYLON CRASSUM, gen. et spec. nov. Pl. XIX. fig. 24.

Fragments of wood with a smooth thin bark, and a tissue wholly composed of elongated cylindrical cells with irregular pores or markings. No pith, medullary rays, nor rings of growth.

The specimens to which the above description refers are fragments, the largest of which may have been 2 inches long, an inch wide, and half an inch thick. They present under a magnifying-glass a fibrous appearance (as if made up of thin threads or wires), from which I have taken the name of the genus. They are calcified, and when sliced show their structures very perfectly. Under the microscope they at first sight remind the observer of the structure of *Prototaxites*; but the cells are of one-third greater diameter than in *P. Logani*, and are destitute of its peculiar markings, and there are no rings of growth or medullary rays. The wood-cells are of great length, somewhat tortuous, loosely aggregated, and much thickened by ligneous deposit, which appears to be traversed by many narrow tortuous lines or pores. The whole stem seems to be perfectly homogeneous, and the only other structure observed was a faint and doubtful trace of the existence of parenchymatous cells in some of the spaces between the fibres. The figures show a longitudinal and cross section, magnified, and a few detached cells or woody fibres still more highly magnified.

With respect to the affinities of this tissue, I can give no opinion. It may have been that of a Plant whose stem, destitute of true vessels and composed of woody fibres imbedded singly in cellular tissue, bore the same relation to that of an Endogen which *Prototaxites* bears to an ordinary Exogen. On the other hand, it has a sufficiently strong resemblance to the fibrous outer bark of some *Sigillariæ* to render it possible that it may have belonged to a Plant of this character, of which the axis and inner bark have perished.

3. NEMATOXYLON TENUE, spec. nov. Pl. XVIII. fig. 23.

Slender stems with thick coaly bark, and woody fibres of much smaller diameter than in the last species, and marked with minute dots.

The stems of this species are small, not exceeding half an inch in diameter, but are distinctly surrounded by a thick, shining, coaly bark. The wood is calcified, and appears to be perfectly homogeneous, and composed of the tissue represented in Pl. XVIII. figs. 23 *a* to 23 *c*, the last two of which are drawn to the same scale as fig. 24 *b*, to show the different dimensions of the cells. It may be doubted if this species has any real affinity with the last, but they correspond in their negative characters, and both appear to indicate the existence of certain woody Plants of singularly simple and homogeneous structure. Many of the small carbonized fragments scattered over the surfaces of the Gaspé sandstones belong to the present species, and were noticed in my former paper on the Plants of Gaspé as aporous tissues of uncertain nature.

4. INCERTÆ SEDIS.

Among Mr. Bell's specimens are many fragments of quite uncertain character. One of these is a stem thickly studded with minute irregularly placed points or tubercles, and having a finely striated surface (Pl. XIX. fig. 25). It resembles the "branching root" figured by Mr. Salter from the Devonian of Stromness. Another is a stem with interrupted ridges, in the manner of *Rhachiopteris striata* from the Devonian of New York, fig. 31. It may be the stipe of a Fern. Another (fig. 29) is a very slender stem marked with minute raised scales or rudimentary leaves, and possibly a *Lycopodites* of the type of *L. Milleri*, Salter. To these I have added, from my own collection, a little Stigmarioid Plant, fig. 31, which, if really a *Stigmaria*, is the most diminutive of the genus; but it may admit of doubt whether it is not an imperfectly preserved Lepidodendroid Plant.

5. ALGÆ. Pl. XIX. figs. 32 & 33.

In Mr. Bell's collection are numerous specimens, apparently of Sea-weeds, resembling the Cauda-galli Fucoid of the Devonian rocks of New York. They appear to include two distinct forms. One of these (fig. 32) consists of cylindrical and dichotomous filaments, and may be referred to the provisional genus *Chondrites*. It appears to be the first or fibrous form of *Fucoides Cauda-galli* mentioned by Vanuxem (Report, p. 128, fig. 30). The other (fig. 33) is a continuous frond, and shows indications of having been thickened or folded at the convex margin. It might be placed in the genus *Zonarites*, and is probably identical with Vanuxem's second or continuous form, for which he proposes the name *Fucoides velum*. Both occasionally appear as if looped or attached at both extremities, as was the case in Vanuxem's specimens. The first-mentioned species, or variety, is found in beds believed to be Upper Silurian, and which contain obscure remains of Land-plants, at Anse à la Barbe in the

Baie de Chaleurs. The second is also from rocks at Gaspé*, supposed to be Upper Silurian, but below those containing Land-plants.

§ IV. *New York.*

In my paper of last year several species were referred to the Cattskill group, being so labelled in the collection of the Geological Survey of New York. Prof. Hall has, however, communicated to me, and published in the 'Canadian Naturalist,' observations recently made by Mr. Way and others, and confirmed by his own examinations, of sections and fossils, which show that the rocks from which these Plants were obtained really belong to the underlying Portage and Chemung groups. This brings the distribution of the Devonian Plants of New York more nearly into harmony with that observed at Gaspé and elsewhere, and leaves the Cattskill group, as now restricted, destitute of that evidence of connexion with the underlying beds which these Plants seemed to afford.

I desire to change the name *Pecopteris* (*Alethopteris*) *decurrens*, of my last paper, into *P. discrepans*†,—a species from the Coal of Pennsylvania having been described by Lesquereux under the former name.

§ V. *Conclusion.*

The present paper raises the number of species obtained from the Devonian rocks of Eastern America to about eighty-two, but does not in any respect invalidate the general conclusions stated in my former paper. Of the whole number of species, only two can with certainty be referred to the Lower Devonian, and these also occur higher in the series. Twenty-one are found in the Middle Devonian, and of these nine or ten ascend to the Upper Devonian, which has afforded about sixty-eight species; and of these probably ten are known in the Carboniferous System. It must be observed, however, that the precise age of the beds at Perry and St. John is uncertain, and that they are referred to the Upper Devonian principally on the evidence of their fossil Plants,—the stratigraphical evidence being sufficient merely to prove their Precarboniferous date.

EXPLANATION OF PLATES XVII.–XIX.

Plate XVII.

Figs. 1 & 2. Portions of pinnæ of *Lycopodites Richardsoni*; (2 *a*) leaves enlarged.
3. *Stigmaria pusilla.*
4. *Carpolithes? siliqua.*

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* Prof. Hall informs me that he has ascertained the ordinary *Fucoides Cauda-galli* of New York to be fragments of spiral forms, which he proposes to describe, under a new generic name, in a forthcoming Report of the Regents of the University of New York. It is possible that the Gaspé fucoids above noticed may also have been spiral in their growth.

† This correction has already been made in the list of errata occurring in vol. xviii. of the Society's Journal, and published, together with the title-page and index of that volume, with No. 73 of the Journal.—Edit.

Figs. 5. Fragment of root of Conifer.
6. Portion of pinna of *Cyclopteris Brownii*; (6 *a*) stipe of *C. Jacksoni.*
7 & 8. *Sphenopteris recurva.*
9. *Cordaïtes flexuosus.*
10. Pinna of a Fern, not named; (10 *a*) portion magnified.
11. *Carpolithes lunatus.*
12 & 13. *Trichomanites filicula.*
14. *Lycopodites comosus*; (14 *a*) portion magnified.
15. *Carpolithes spicatus.*
16. Fern, not named.
17. Pinna of *Cyclopteris Rogersi.*
18. Stipe of *Cyclopteris Rogersi.*

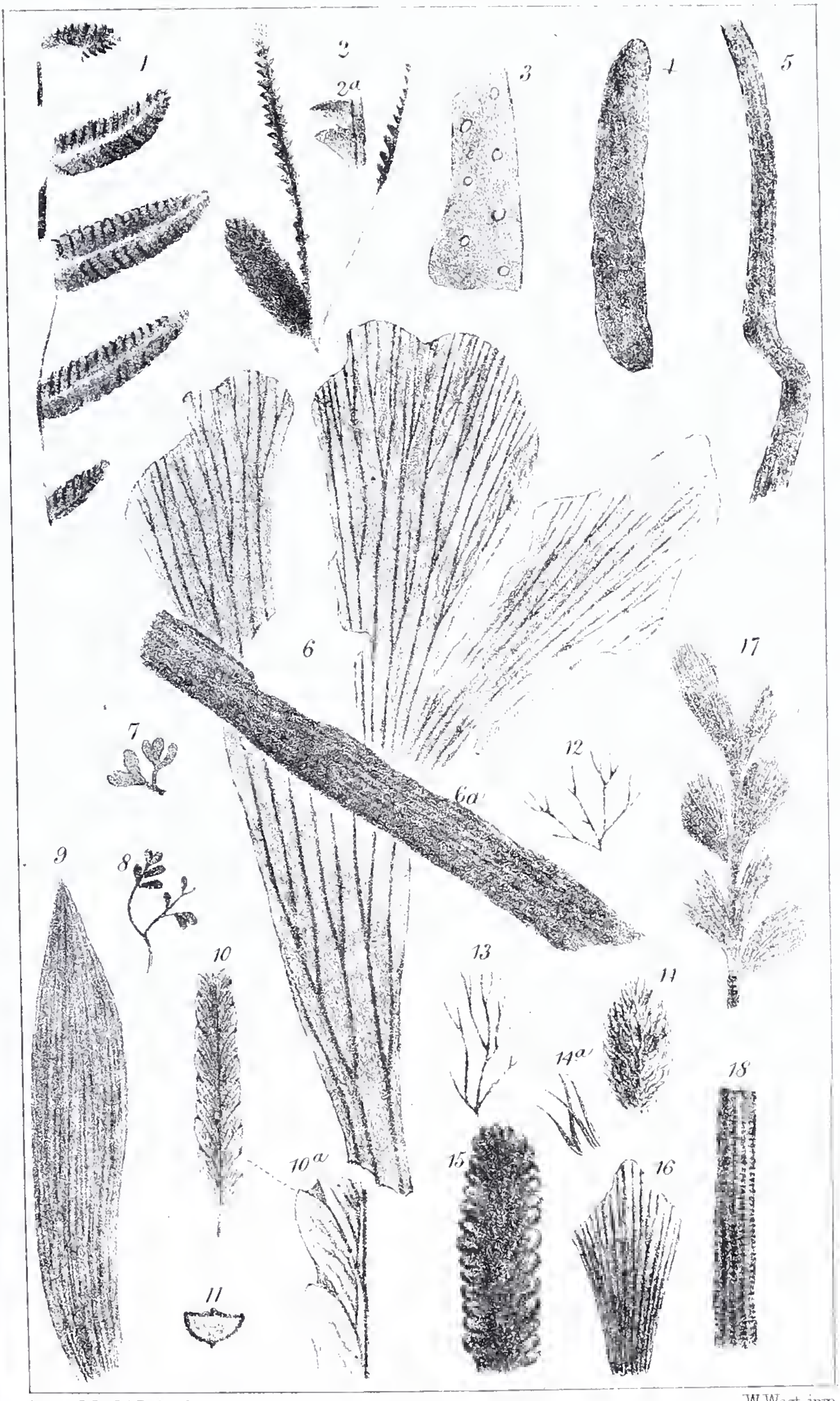
Plate XVIII.

Fig. 19. *Leptophlœum rhombicum*, restored; (19 *a*) leaf.
20. Fragment of bark of Conifer.
21. *Anarthrocanna Perryana.*
22. Rhizoma of *Psilophyton princeps*; (22 *a*) cross section of the same, showing the axis and bark; (22 *b*) portion of cross section magnified, showing remains of the bark β, of inner bark ϵ, of the woody sheath of the axis γ, of the scalariform centre of the axis δ; (22 *c*) cross section of the tissue of the axis, magnified 100 diameters; (22 *d*) longitudinal section of the tissue of the axis; (22 *e*) cross section of the outer bark; (22 *f*) longitudinal section of the axis of the aërial stem for comparison with *c*; (22 *g*) cross section of the axis of another specimen, magnified as in *c*.
23. Portion of the stem of *Nematoxylon tenue*; (23 *a*) cross section slightly enlarged; (23 *b*) longitudinal section; (23 *c*) transverse section, magnified 200 diameters.

Plate XIX.

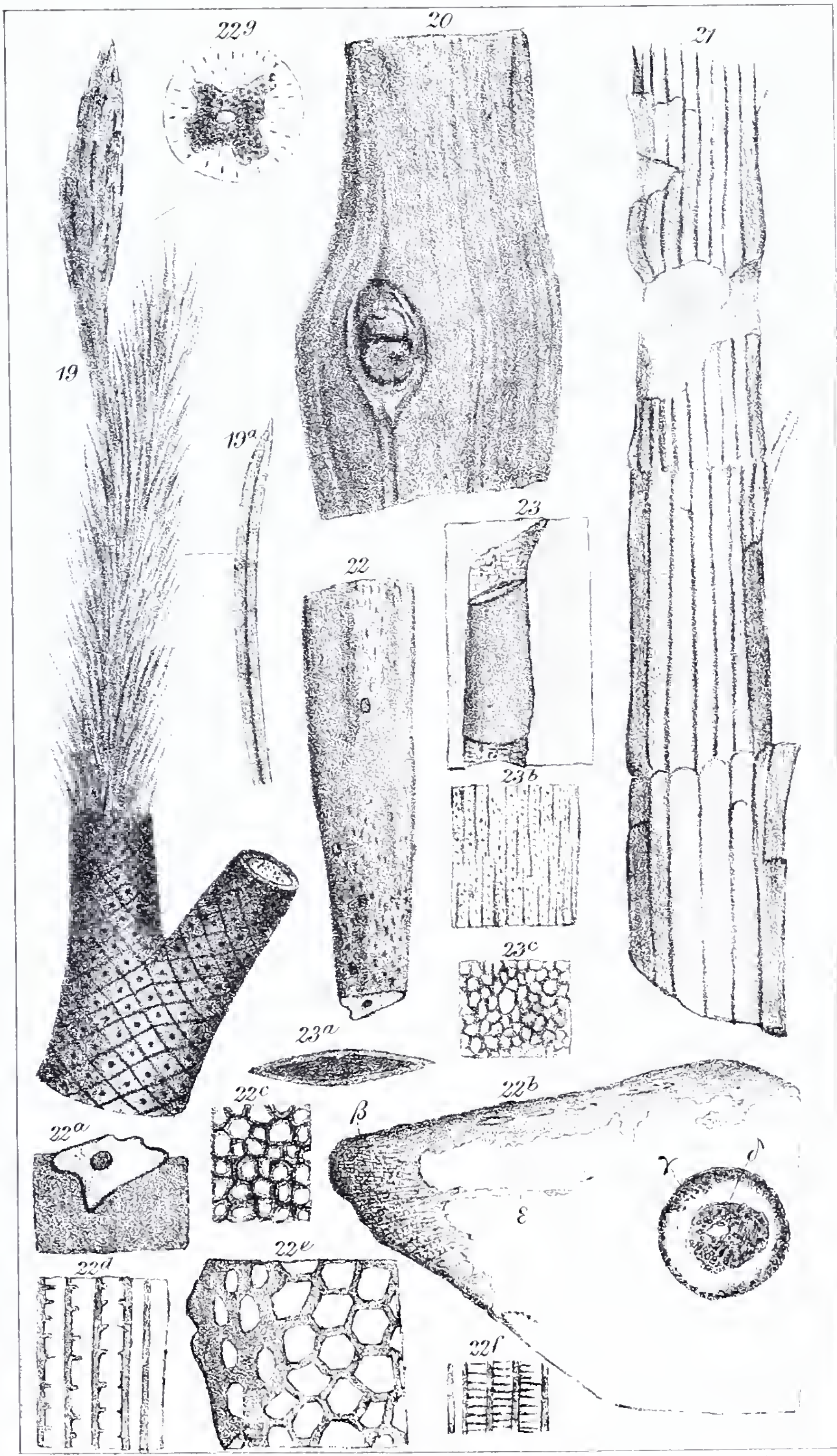
Fig. 24. Longitudinal section of the stem of *Nematoxylon crassum*, magnified 100 diameters; (24 *a*) cross section; (24 *b*) transverse section of a few cells, magnified 200 diameters.
25. Stem with tubercles; (25 *a*) magnified.
26. Pinna of *Cyclopteris Jacksoni*; (26 *a*) separate pinnule; (26 *b*) diagram of venation; (26 *c*) small variety.
27. Pinna of *Cyclopteris Rogersi*; (27 *a*) separate pinnule; (27 *b*) diagram of venation.
28. Pinna of *Cyclopteris Halliana*; (28 *a*) separate pinnule; (28 *b*) diagram of venation.
29. *Lycopodites.*
30. Stem with ridges.
31. Stigmaria ?; (31 *a*) areole magnified.
32. *Fucoides* (*Chondrites*) *Cauda-galli* (reduced).
33. *Fucoides* (*Zonarites*) *velum* (reduced).

Quart. Journ. Geol. Soc. Vol. XIX. Pl. XVII.



J.W.D. del. G. West lith.
W. West imp.

DEVONIAN PLANTS, N.E. AMERICA.



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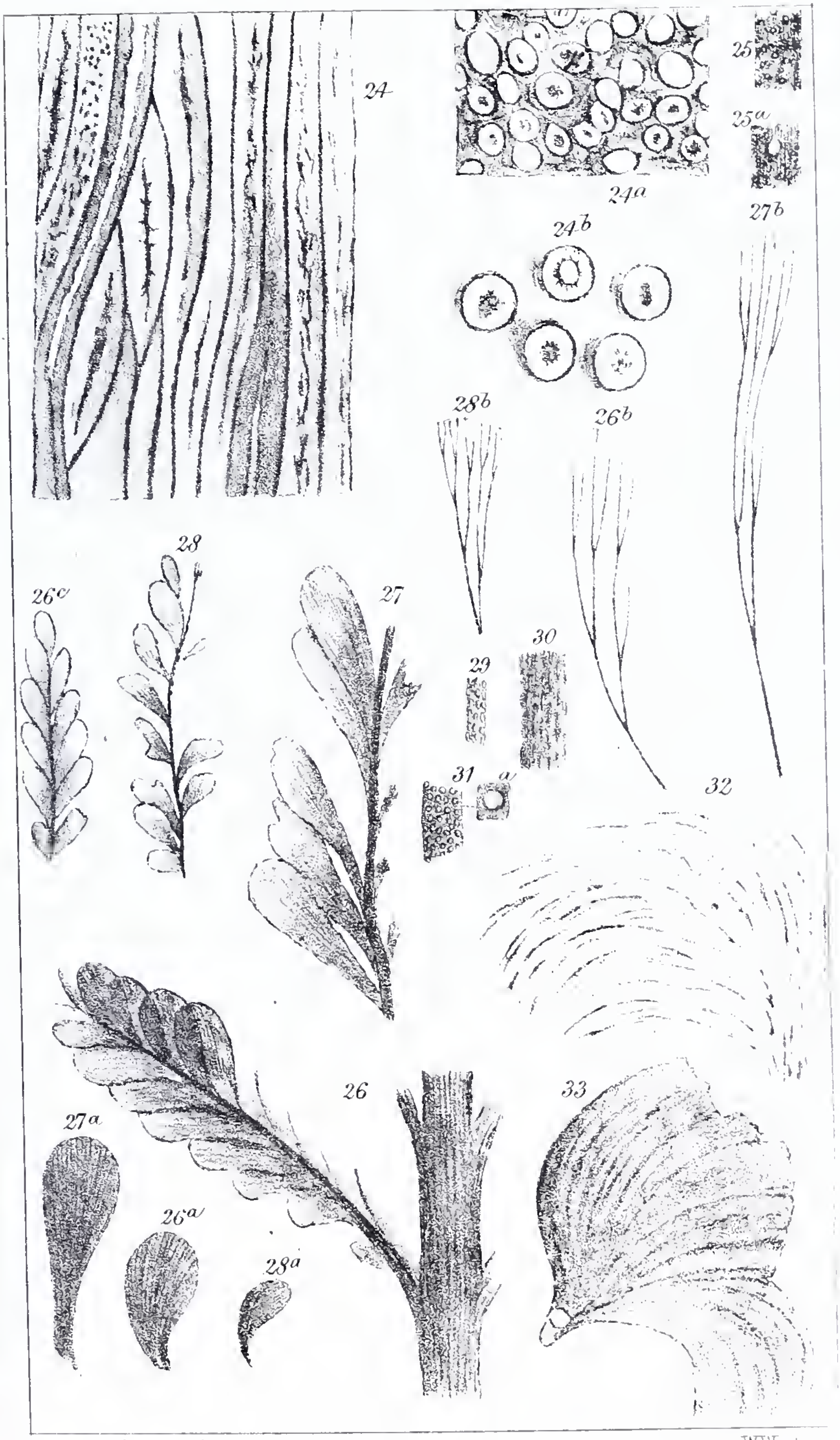
DEVONIAN PLANTS, N.E. AMERICA.



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W. West imp.

DEVONIAN PLANTS, N.E. AMERICA.

Aug 1862

DESCRIPTION OF SPECIMENS

OF

FOSSIL REPTILIA

DISCOVERED IN THE COAL-MEASURES

OF THE

SOUTH JOGGINS, NOVA SCOTIA,

BY DR. J. W. DAWSON, F.G.S., &c.

BY PROFESSOR OWEN, F.R.S., F.G.S.

PLATES IX. & X.

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The following specimens were transmitted to the Museum of the Geological Society by Dr. Dawson, in a series of boxes and parcels, most of which are numbered according to a list accompanying them, and have been submitted, by his desire, to my inspection. The descriptions will follow in the order of that list.

"Box No. 1.—*Hylonomus Lyelli*, Dawson."

This specimen is imbedded in a portion of a thin layer of carbonaceous matter, measuring six inches by four inches. It consists of scattered parts and impressions of vertebræ, ribs, limb-bones, and part of a cranium crushed, including part of a maxillary bone with teeth (Pl. IX. figs. 1–5). Not any of the bones are entire: all the long bones, even the ribs, are hollow; and the cavity is enclosed by a compact wall of almost uniform thinness throughout each bone, indicative that such cavity was not properly a medullary one, in the sense of having been excavated by absorption after complete consolidation of the bone by the ossifying process, but was posthumous, and due to the solution of the primitive cartilaginous mould of the bone, which had remained unchanged by ossification in the living species. I conclude, therefore, that these hollow long bones (and, indeed, the bodies of the vertebræ seem only to have received a partial and superficial crust of bone) were originally solid, and composed, like the bones in most *Batrachia*, especially the Perennibranchiates, of an external osseous crust, enclosing solid cartilage. The body of the vertebra (figs. 1 & 2) is chiefly represented by a downward growth of the base of the neural arch (*n*); and in the best-preserved specimen there seems to be a distinct inferior plate (*c*), with a median longitudinal channel on the lower surface,—such vertebræ belonging to the dorsal region: the cylindrical cavity of the centrum was doubtless occupied by the notochord. The neural arch developes a short, broad diapophys is (*d*), to which the rib articulates: it also has zygapophyses both before (*z*) and behind (*z'*), and a moderately long truncate spine (*n s*), slightly expanding in the fore-and-aft direction to its summit. The ribs are of various lengths, the shorter ones straight, the longer ones slightly bent; the best-preserved of these have an expanded end, slightly notched (fig. 3), but none show a distinctly bifurcate extremity. Those limb-bones, metapodials or phalanges, which have their articular end preserved, show it to be flattened (fig. 4),—not fashioned for a condyloid or trochlear joint with articular cartilage and synovial membrane, but adapted for a simple ligamentous union, as in the digits of the Salamanders, Turtles, *Amphiume*, and *Proteus*. One end of some of these bones shows a short longitudinal impression at the middle. The surface of some of the larger long bones shows longitudinal striation, indicative of a fibrous structure like that of the bones in some fishes. The maxillary fragment in the slab, No. 1, which Dr. Dawson supposes to belong to another individual of *Hylonomus*, is figured of twice the natural size in Pl. IX. fig. 5. The bone, in respect to its proportions as to length and depth, to the number, size, and shape of the teeth it contains, and to the indications of sculpturing of the outer surface, resembles the maxillary and dentary bones of *Archegosaurus*. A series of twenty-four teeth occupies a part of the alveolar border, *a*, 6 millimeters (nearly 3 lines) in extent; but impressions and fragmentary traces of others beyond show that there were at least 40 teeth in a row on one side of the upper jaw. There is an indication of the lower border of the orbit *o*, above the hinder third of this series. The teeth increase gradually in length as they approach this part; their crowns are slender, subcompressed transversely, pointed, but not sharply, with evidence of alternate shedding. They are partially anchylosed to shallow alveolar depressions on the border, towards the inner side, of the jaw-bone. Their enamelled surface is smooth, and shows a whiter colour than the bone itself.

"Box No. 2.—*Hylonomus aciedentatus*, Dawson."

This contains two portions of shaly carbonaceous matter. In one is imbedded the major part of a maxillary bone (Pl. IX. fig. 6), with the inner side exposed, which is smooth, and demonstrates the fixation of the teeth not to be as in the pleurodont lizard, but according to the acrodont type; the sockets, however, are shallow, and the simple bases of the teeth are partially anchylosed thereto, as in *Archegosaurus* and *Labyrinthodon*, and that of the largest tooth (being exposed by removal of the inner alveolar wall) shows the fossa due to the matrix of the successional tooth. The teeth are not so bent as to indicate which is the front or which the hind end of this maxillary bone. The teeth are the smallest at both ends, gradually increasing as they recede from one end, and rapidly from the other, near to which are four or five teeth, four times the length of the terminal ones of the series. I suspect this to be the fore part of the bone. The proportions and shape of the crown are much as in the *Hylonomus Lyelli*; but there seems to be a greater variety of length in the teeth of *Hylonomus aciedentatus*. In both species the dentition indicates a small insectivorous or vermivorous reptile.

A second portion of coal-shale, in box No. 2 (marked 5 *a*), contains the impression, with a small portion of one end, of a dentary bone of the lower jaw, which held a series of at least 40 teeth (Pl. IX. fig. 7*a*). These, in size and proportion, agree with those of *Hylonomus Lyelli*, in No. 1. The teeth very gradually decrease from the middle to the two ends, especially to the anterior one. In the number, proportions, and close arrangement of the teeth, this dentary bone agrees with that of the *Archegosaurus*. Lizards have not so many teeth.

A third portion of coal (5 *a*), in box No. 2, contained the slender-pointed end of a jaw-bone, with a close-set series of about 25 teeth in an extent of 13 millimeters, or 6½ lines (Pl. IX. fig. 9). These teeth increase from the pointed end of the bone to about the tenth tooth, and thence continue with little difference of size: the crown expands slightly beyond the implanted base, before narrowing to the rather blunt-pointed end. The outer surface of the jaw-bone shows a striated or strio-punctate pattern of sculpture.

A fourth portion (5 *b*) included parts of the bones of a short natatory fore limb (Pl. IX. fig. 10). The humerus (*h*) has an expanded proximal end, with three ridges, two of them more extended than the other; the shaft of the bone is rather bent. This bone has been dislocated from the radius (*r*) and ulna (*u*), beyond which are evidences of three, if not four, digits; these progressively increase in length to the fourth (*iv*), of which, and of the third, impressions and parts of three successive phalanges are shown. These are slightly expanded at their flattened articular ends, at which the longitudinal impressions may be seen in two instances; but the joints were syndesmotic, as in *Archegosaurus* and modern aquatic batrachian reptiles; and the humerus and antebrachium are short in proportion to the manus, although not to such a degree as in *Archegosaurus*.

The group of dermal scutes includes some (Pl. IX. fig. 13 *b*, *c*) which are nearly perfect, of an oval form, smooth on the inner surface, with a low longitudinal ridge, half the length of the scute, on the outer surface; the external layer is of ganoid hardness; the internal structure is cellular. They indicate the nature of the covering of one of the species of *Hylonomus*.

"Box No. 3.—*Hylonomus Wymani*, Dawson."

The remains of foot-bones (Pl. IX. fig. 11) in one of the portions of coal-shale in this box show a tridactyle structure, with more slender proportions than in the *Hylonomus aciedentatus*; but the phalanges have the same flat joints and incomplete ossification, a thin external crust of bone enclosing a cavity which had been occupied by cartilage: they much resemble the phalanges of the Axolotl.

A second portion contains a series of six or seven crushed neural arches of vertebræ (Pl. IX. fig. 12), of a length twice their breadth, with horizontal zygapophyses—the spines probably broken away. In the proportion of length to breadth, these vertebræ resemble those of *Proteus**. There is no evidence of an ossified centrum in any part of this series; but there are some elongated vacuities, which seem to represent the unossified parts of centrums, partially cased by thin bone. The impressions, with filmy remains of bones of a second series of six vertebræ, of similar slender proportions, are preserved in the same portion of coal.

Pl. IX. fig. 13 *a* represents one of the largest specimens of a rib, partly in bone, partly in impression, with an expanded, slightly notched head, as in the ribs of the Axolotl, but of greater length and more curved than in any modern naked Batrachian: it is hollow, as in the shorter specimens, with a thin outer crust.

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* Cuvier, Ossemens Fossiles, v. pt. ii. pl. xxvii. fig. 14.

Near the specimen, and near the jaw of *Hylonomus* (fig. 7*a*), are specimens of the dermal scutes. They are oval, flattened, smooth and slightly concave on the inner side, with parallel curved striations on the outer surface.

Pl. IX. fig. 14 is the dentary bone, with very small, equal, close-set teeth, eleven being in the extent of 2 millimeters; they best accord in character with those of the upper jaw of *Hylonomus Lyelli* (fig. 5), to which species I believe this lower jaw to belong.

Pl. IX. fig. 15 is part of an upper jaw, with teeth less closely arranged, and very small in proportion to the breadth of the bone. It is of a *Hylonomus*, and exhibits on the outer surface of part of the bone the pits and radiating furrows which characterize the outer sculpturing of the skull-bones of *Archegosaurus*.

"Parcel No. 4.—Jaw of a Reptile, supposed to be new."
Hylerpeton Dawsoni, Ow. (Pl. IX. fig. 16).

This specimen consists of the left ramus of a lower jaw, which has been dislocated from the crushed head, of which the fore end of the left premaxillary (*p*) is preserved, terminating near the middle of the series of the teeth of the more advanced mandible. A fragment of the left maxillary (*m*), which has been separated from the premaxillary, overlaps the hinder mandibular teeth. The fore part of the mandible is wanting. The teeth in the remaining part are larger and fewer, in proportion to the jaw-bone, than in *Hylonomus* or *Dendrerpeton*. They have thicker and more obtusely terminated crowns; they are close-set where the series is complete at the fore part of the jaw, and their base appears to have been anchylosed to shallow depressions on the alveolar surface. The shape of what is preserved of the upper jaw affords the only evidence, and not very decisively, that the present fossil is not part of a fish. It inclines the balance, however, to the reptilian side; and, accepting such indication of the class-relations of the fossil, it must be referred to a genus of *Reptilia* distinct from those it is associated with in the Nova-Scotian coal, and for which genus I would suggest the term *Hylerpeton*.

A small part of the external surface of the dentary bone shows a longitudinally wrinkled and striate or fibrous character. The outer bony wall, broken away from the hinder half of the dentary, shows a large cavity, now occupied by a fine greyish matrix (*x*), with a smooth surface, the bony wall of which cavity has been thin and compact. We have here the mark of incomplete ossification, like that in the skeleton of *Archegosaurus*. The crushed fore part of the right dentary bone, with remains of a few teeth, is below the left dentary, and exemplifies a similar structure. The teeth slightly diminish, though more in breadth than length, towards the fore part of the series: here there are nine teeth in an alveolar extent of 10 millimeters, or nearly 5 lines. The portion of jaw, figured of twice the natural size, in fig. 17, shows the anchylosis of the base of the teeth in a shallow groove or alveolus: the base of the teeth is longitudinally fissured, but the fissures do not extend upon the exserted crown. In their general characters, the teeth manifest at least as close a resemblance to those of *Ganocephala* as of *Lacertia* or any higher group of *Reptilia*; whilst their mode of implantation, with the structure and sculpturing of the bone, weigh in favour of its relations to the lower and earlier order of the cold-blooded Vertebrates.

"No. 5.—Skin and dermal plates of *Hylonomus* (?), probably *H. Lyelli.*"

The specimen so marked shows three oblong plates (Pl. X. *a*, *b*, *c*, fig. 2), with a slightly concave surface, finely striate transversely, and with one margin free, obtuse, and well defined. Continuous with this is a granulate surface, like shagreen, of small, close-set, subelliptic scales or tubercles (*d*).

Another portion of coal-shale shows a layer, and an impression of a continuous part of the same layer, of integument (Pl. X. fig. 1) which has been defended by similar small and subimbricate scales. From their state of preservation, these were probably bony or ganoid. I do not know the evidence in proof of their belonging to *Hylonomus*.

Pl. X. fig. 3 is a portion of the bones of the cranium, including the frontal and parts of the prefrontal, postfrontal, parietal, postorbital, and supertemporal bones of probably a *Hylonomus*. They show the skull to have been broad and much depressed: the superorbital border (*o*) is formed by the pre- and post-frontals. In most of the bones, and especially the supertemporal plate, *s*, the outer surface is sculptured according to the pattern shown in the skull of *Archegosaurus*.

Pl. X. fig. 4 is a portion of a jaw, with small equal teeth having the characters of those of *Hylonomus*, and with a sculptured external surface like that in Pl. X. fig. 3 and in Pl. IX. fig. 15.

Passing over the interesting examples of probably the food of the small reptiles, shown in No. 5 (*Pupa vetusta*, Dawson) and No. 7 (*Xylobius sigillarius*, Dawson), I come to

"No. 8. Loose specimens of *Dendrerpeton Acadianum*, Ow. (a nearly complete skeleton)."

The chief addition to the evidence already recorded of the characters of this reptile* are, 1st, the incompletely ossified conditions of the endoskeleton, manifested even in the slender ribs, which have their cavities filled with matrix, as formerly with the primitive cartilage; 2nd, the shape of the head (Pl. X. fig. 5 *a*); 3rd, the superficial markings of the cranial bones (fig. 6) and scutes; 4th, the batrachian type of the ilium, and probably of the pelvis, fig. 7.

The skull (Pl. X. fig. 5 *a*) is broad, depressed, obtusely rounded anteriorly, rather Labyrinthodontal than Archegosaural in shape; although, in the species of both these early types of batrachian air-breathers, there is such a known range of variation as to detract from the value of the character of the degree of obtuseness of the muzzle. Unfortunately, the occipital part of the skull, which would have afforded the test of the mode of its articulation with the atlas, is wanting. The Labyrinthodonts have a pair of condyles, as in *Rana*: the *Ganocephala*, like *Lepidosiren*, show no bony joint between the basi-occipital and atlas.

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* Quart. Journ. Geol. Soc. vol. ix. p. 64, &c.

The under surface of the bones forming the roof of the skull is exposed in this specimen. As in *Archegosaurus* and *Hylonomus*, the frontal (11) is separated from the orbital border (o, o) by the union of the post- (12) and pre- (14) frontals. The temporal fossæ were roofed over with bone; and these cranial bones show their external surface, fig. 6, to be sculptured with the beautiful and characteristic pattern exhibited in the supertemporal plate of the specimen of *Hylonomus*, fig. 3. This pattern may be seen on the cranial bones of some ganoid fishes, and on those of *Archegosaurus* and *Labyrinthodon*. The orbits in *Dendrerpeton* are circular, divided by a bony tract of more than their own diameter: they seem to have been midway between the two ends of the skull; but the hinder part of this is not complete in the specimen. The small nostrils are not midway between the orbits and the muzzle, but nearer the latter. The few teeth preserved at this part of the skull show the plication of the base due to the entering folds of the cement, and yield, on a transverse section (fig. 5 *b*), the same approach to the labyrinthic character as in *Archegosaurus*. Their bases are confluent with the alveolar depressions: there are no tusks as in *Labyrinthodon*.

A short straight bone, uniting with two other divergent ones, appears to be the ilium; and I regard the specimen Pl. X. fig. 7 as part of the pelvis of *Dendrerpeton*: the ossified part of each of these bones is a thin outer crust. The ilium, by its shortness and straight subcylindrical rib-like form, agrees with that in *Archegosaurus* and in modern Perennibranchiate reptiles. In *Labyrinthodon* the ilium expands in some measure according to the Crocodilian type of the bone.

The short proportions and simplicity of shape and structure of the limb-bones combine, with the above-mentioned characters, to demonstrate the Ganocephalous nature of this Nova-Scotian reptile of the Coal-period.

Dendrerpeton, like *Hylonomus* and *Archegosaurus*, shows the affinity (shall we call it?) or analogy to the ganoid fishes, not only in the character of the cranial bones, but in the retention of a covering of the body by ganoid scales: these are elliptic, smooth on their inner surface, with a slight indication of a ridge, about half the length of the scale, on the external surface,—at least, in certain of the scales, and probably those along the back.

The genus *Hylonomus* also, although with more minute and simple teeth, had the skin defended by similar elliptic or suboval ganoid scales. Much remains to be determined as to the structure of the skull: nevertheless such cranial bones as have been obtained (Pl. X. figs. 3, & 5*a*, 6) exemplify the Ganocephalous sculpturing; while the arrested state of ossification of the endoskeleton and the characters of the limb-bones sustain the reference of the genus to the order *Ganocephala*.

After careful scrutiny of all the specimens confided to my inspection by Dr. Dawson, I have not met with decisive evidence of a member of any of the orders of *Reptilia* represented by species of the Oolitic or later series of deposits. Some, as (*e.g.*) *Baphetes*, may be Labyrinthodont, but the rest are Ganocephalous; and *Baphetes* may possibly belong to this lower group of palæozoic air-breathing Vertebrates.

DESCRIPTION OF THE PLATES.

Plate IX.

Fig. 1. *Hylonomus Lyelli*, dorsal vertebra, three times magnified: side view.
Fig. 2. ———————, dorsal vertebra, three times magnified: transverse section.
Fig. 3. ———————, one of the longer ribs, twice nat. size; the end showing the hollow.
Fig. 4. ———————, metapodial and phalangial bones, twice nat. size.
Fig. 5. ———————, upper maxillary and part of orbit, twice nat. size.
Fig. 6. Part of upper maxillary and teeth of *Hylonomus aciedentatus*.
Fig. 7*a*. Impression and remains of the dentary bone of the lower jaw of *Hylonomus aciedentatus*, and of a scute, three times magnified.
Fig. 8. Part of the dentary bone of a young, or small kind of *Hylonomus*, three times magnified.
Fig. 9. The anterior end of a jaw-bone of *Hylonomus*, twice nat. size.
Fig. 10. Bones of the fore limb of *Hylonomus*, three times magnified.
Fig. 11. Bones of a foot of *Hylonomus Wymanni*, twice nat. size.
Fig. 12. Series of (caudal?) vertebræ of *Hylonomus Wymanni*, twice nat. size
Fig. 13. Rib (*a*) and two scutes (*b* and *c*) of *Hylonomus*, twice nat. size.
Fig. 14. Right dentary part of lower jaw of *Hylonomus Lyelli*, twice nat. size.
Fig. 15. Part of the upper jaw and teeth of a *Hylonomus*, three times magnified.
Fig. 16. Parts of upper and lower jaws of *Hylerpeton Dawsoni*, nat. size.
Fig. 17. Small part of jaw of *Hylerpeton*, showing the mode of implantation of the teeth; twice nat. size.
Fig. 18. A group of the scutes of *Hylerpeton* (?); twice magnified.

Plate X.

Figs. 1 & 2. Dermal scutes and markings of the skin of *Hylonomus*?
Fig. 3. Portion of the frontal and contiguous cranial bones of a *Hylonomus*, twice nat. size.
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Fig. 5 *a*. Inner surface of upper part of the skull of *Dendrerpeton Acadianum*, nat. size. 5 *b*, magnified section of base of tooth.
Fig. 6. Outer surface of supertemporal bone of *Dendrerpeton Acadianum*, twice nat. size.
Fig. 7. Ilium and parts of pubis and ischium of *Dendrerpeton Acadianum*.

W West imp.

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Quart. Journ. Geol. Soc. Vol. XVIII. Pl. X.

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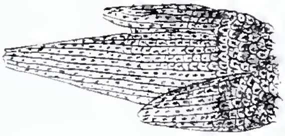

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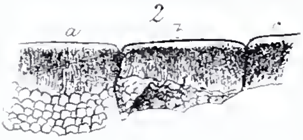

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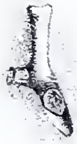

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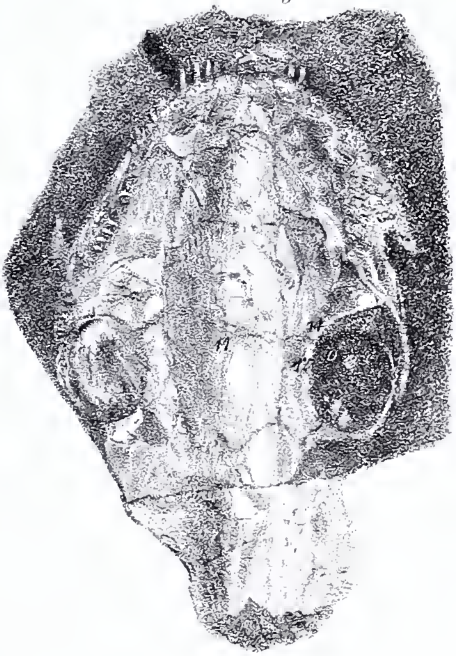

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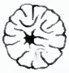

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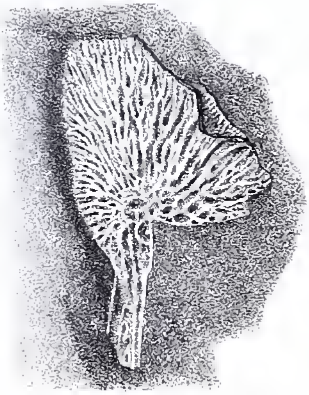

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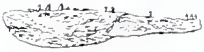

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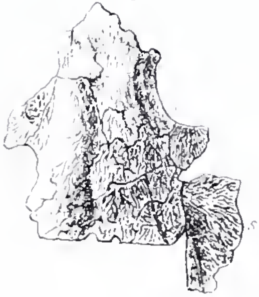

Dinkel lith

W West imp.

REPTILIAN REMAINS FROM NOVA SCOTIA.

[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for May* 1866.]

ON THE
CONDITIONS
OF THE
DEPOSITION OF COAL,
MORE ESPECIALLY AS ILLUSTRATED
BY THE
COAL-FORMATION OF NOVA SCOTIA
AND
NEW BRUNSWICK.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

BY

J. W. DAWSON, LL.D., F.R.S., F.G.S.,
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§ I. INTRODUCTION.

IN several former papers presented to this Society, I have endeavoured to illustrate the arrangement of the Carboniferous rocks of Nova Scotia, and to direct attention to their organic remains, the structures found in their coals, and the evidence which they afford as to the mode of accumulation of that mineral. The present paper is intended as the summing up and completion of these researches, with the addition of the new facts resulting from a careful study of the microscopic structure of more than seventy beds of coal occurring in the South-Joggins section, and of the fossil plants associated with them. These results will, I hope, throw much additional light on some of the more difficult problems connected with the theory of the accumulation of vegetable matter in the Carboniferous period, and its conversion into coal.

The subjects to which I propose to direct attention may be conveniently arranged under the following heads:—

(1) General considerations relating to the physical conditions of the Carboniferous period in Nova Scotia.

(2) Details of the character and contents of the several beds of coal in the Joggins section, arranged in the order of Logan's Sectional List.

(3) Remarks on the genera of animals and plants whose remains occur in the coal, and on their connexion with its accumulation.

§ II. GENERAL CONSIDERATIONS RELATING TO PHYSICAL CONDITIONS.

1. *Physical Characters of the several Coal-formations.*—The total vertical thickness of the immense mass of sediment constituting the Carboniferous system in Nova Scotia may be estimated from the fact that Sir W. E. Logan has ascertained by actual measurement at the Joggins a thickness of 14,570 feet; and this does not include the lowest member of the series, which, if developed and exposed in that locality, would raise the aggregate to at least 16,000 feet. It is certain, however, that the thickness is very variable, and that in some districts particular members of the series are wanting, or are only slenderly developed. Still the section at the Joggins is by no means an exceptional one, since I have been obliged to assign to the Carboniferous deposits of Pictou, on the evidence of the sections exposed in that district, a thickness of about 16,000* feet; and Mr. Brown has estimated the Coal-formation of Cape Breton, exclusive of the Lower Carboniferous, at 10,000 feet in thickness†.

When fully developed, the whole Carboniferous series may be arranged in the following subordinate groups or formations, the limits of which are, however, in most cases not clearly defined:—

a. *The Upper Coal-formation.*—It consists of sandstones, shales, and conglomerates, with a few thin beds of limestone and coal. *Calamites Suckovii*, *Annularia galioides*, *Cordaites simplex*, *Alethopteris nervosa*, *Pecopteris arborescens*, *Dadoxylon materiarium*, *Lepidophloios parvus*, and *Sigillaria scutellata*, are among its characteristic vegetable fossils.

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* Quart. Journ. Geol. Soc. vol. i. p. 329.

† *Ibid.* vol. vi. p. 116.

b. *The Middle Coal-formation, or Coal-measures proper.*—This series includes the productive beds of coal, and is destitute of properly marine limestones. Beds tinged with peroxide of iron are less common in this formation than in any of the others. Dark-coloured shales and grey sandstones prevail, and there are no conglomerates. *Sigillariæ* and *Stigmariæ* of many species are the most conspicuous and abundant fossils, but Ferns, *Cordaites*, and *Calamites* are also extremely abundant, and all the genera of Carboniferous plants are represented. Many beds, especially those in the vicinity of layers of coal, contain minute *Entomostraca*, shells of the genus *Anthracomya* (*Naiadites*), *Spirorbis carbonarius*, and remains of ganoid and placoid fishes.

c. *The "Millstone-grit" Formation.*—This name, though not in all cases lithologically appropriate, has been borrowed from English geology to designate the group of sandstones, shales, and conglomerates, destitute of coal, or nearly so, and with few fossil plants, which underlies the Coal-measures. In its upper and middle part it includes thick beds of coarse grey sandstone holding prostrate trunks of coniferous trees (*Dadoxylon Acadianum*). In its lower part red and comparatively soft beds prevail.

d. *The Lower Carboniferous Marine Formation.*—The essential features of this formation are thick beds of marine limestone, characterized principally by numerous Brachiopods, especially *Productus Cora*, *P. semireticulatus*, *Athyris subtilita*, and *Terebratula sufflata**, with other marine invertebrates. Associated with these limestones are beds of gypsum, and they are enclosed in thick deposits of sandstone, clay, and marl, of prevailing red colours.

e. *The Lower Carboniferous Coal-measures, or Lower Coal-measures.*—In some localities these resemble in mineral character the true Coal-measures. In others they present a great thickness of peculiar bituminous and calcareous shales. They usually contain in their lower part thick beds of conglomerate, and coarse sandstone which in some places prevail to the exclusion of the finer beds. The characteristic plants of these beds are *Lepidodendron corrugatum*, and *Cyclopteris Acadica*, with *Dadoxylon antiquius*, and *Alethopteris heterophylla*†. They also contain locally great quantities of remains of fishes, and many Entomostraceans, among which are *Leaia Leidyi* and an *Estheria*, also *Leperditia subrecta*, Portlock, *Beyrichia colliculus*, Eichw., and a *Cythere*‡, probably new.

The last two groups are equivalent to the "Sub-carboniferous" of some American geologists; but independently of the objection to the use of a term which would seem to imply a formation under, and distinct from, the Carboniferous, and of undetermined age, I find in Nova Scotia no reason, either palæontological or stratigraphical, for any greater distinction than that implied in the term Lower

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* See Davidson "On Lower Carboniferous Brachiopoda from Nova Scotia," Quart. Journ. Geol. Soc. vol. xix. p. 158.

† Dawson, "On the Lower Coal-measures," &c., Quart. Journ. Geol. Soc. vol. xv. p. 62.

‡ Prof. Jones has kindly determined these species.

Carboniferous. The Lower Coal-measures are, it is true, more distinct in their flora from the Middle Coal-measures than the latter from the Upper Coal-formation; but still many species are common to the two former, and the difference is small as compared with that between the Lower Carboniferous and the Upper Devonian. The Devonian rocks are also in this region unconformable to the Carboniferous, having been disturbed and altered prior to the deposition of the latter; while no want of conformity, except of the local character hereafter to be noticed, occurs in the Carboniferous.

2. *Physical Conditions attending the Deposition of the Coal-formations.*—The conditions of deposit implied in the mineral character of the several formations above described, would appear to be of three leading kinds:—(1) The deposition of coarse sediment in shallow water, with local changes leading to the alternation of clay, sand, and gravel. This predominates at the beginning of the period, recurs after the deposition of the marine limestones in the formation of the "Millstone-grit," and again prevails in the Upper Coal-formation. (2) The growth of corals and shellfish in deep clear water, along with the precipitation of crystalline limestone and gypsum. These conditions occurred during the formation of the Lower Carboniferous Limestone and its associated gypsum. (3) The deposition of fine sediment, and the accumulation of vegetable matter in beds of coal and carbonaceous and bituminous shale, and of mixed vegetable and animal matters in the beds of bituminous limestone and calcareo-bituminous shale. These conditions were those of the Middle Coal-formation.

Within the limits of Nova Scotia, these conditions of deposition applied, not to a wide and uninterrupted space, but to an area limited and traversed by bands of Silurian and Devonian rocks, already partially metamorphosed and elevated above the sea, and along the margins of which igneous action still continued, as evidenced by the beds of trap intercalated in the Lower Carboniferous*; while about the close of the Devonian period still more important injections and intrusions of igneous matter had occurred, as shown by the granitic dykes and masses which traverse the Devonian beds, but have not penetrated the Carboniferous†. There is evidence, however, in the Carboniferous rocks of the Magdalen Islands and of Newfoundland, and in the fringes of such rocks on parts of the coast of Nova Scotia‡ and New England, that the area in question was only a part of a far more extensive region of Carboniferous deposition, the greater part of which is still under the waters of the Atlantic and of the Gulf of St. Lawrence.

There is ample proof that most of the coarser matter of the Carboniferous rocks was derived from the neighbouring metamorphic ridges; but much of the finer material was probably drifted from more distant sources. There seems no good reason to doubt that in the Carboniferous period, and especially in those portions of it in which the areas now under consideration were in the condition of shallow seas or swampy flats, the greater part of the Laurentian and Silurian districts of North America existed as land; while the great number of Coal-formation plants common to Europe and America may indicate the existence of intermediate lands now submerged. From such lands, undergoing waste during the long Carboniferous time, the materials of the shales and finer sandstones may have been derived.

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* Dawson, Quart. Journ. Geol. Soc. vol. i. p. 329.

† Dawson, Canadian Naturalist, 1860, p. 142.

‡ Jukes's 'Newfoundland;' 'Acad. Geology,' p. 274.

Taking this view of the source of the sediment, we should infer that the time of the formation of the marine limestones was that of greatest depression of the land, when the local ridges of older rock were mere reefs and islets, and when sediment from more distant lands was deposited only at intervals. We should also infer that the time of the formation of the coal-beds was that of greatest elevation, when the former sea-bottoms had become land-surfaces or flats, exposed only to occasional inundation, and when rivers were bearing downward from large continental regions great quantities of fine silt. Further, the conditions of the Millstone-grit and of the Newer Coal-formation must have been of an intermediate character, requiring wide sea-areas receiving great quantities of sediment, and on this account, as well as because of their shallowness, unfavourable to marine life, while the areas of vegetable growth were also of limited extent.

It would also follow that when the Lower Coal-measures and conglomerates were formed, the land was slowly subsiding; that in the time of the marine limestones it attained to its greatest depression, and long remained nearly stationary; that in the Millstone-grit period there was re-elevation, and that in the period of the Middle Coal-formation and Newer Coal-formation there was again subsidence, slow and interrupted at first, but subsequently of greater amount. From the absence of Permian deposits it may be inferred that elevation again took place at the close of the Carboniferous period, to such an extent as to preclude further deposition in the area in question; while the red sandstone and trap of Mesozoic age indicate the recurrence at that time of conditions somewhat similar to those of the beginning of the Carboniferous period.

The general phenomena of deposition above indicated apply to all the Carboniferous areas of Nova Scotia and New Brunswick, and, so far as known, to those of the Magdalen Islands and of Newfoundland. But, as I have pointed out in 'Acadian Geology,' numerous local diversities occur, in consequence of the interference of the older elevated ridges with the regularity of deposition. In some places the entire Lower Carboniferous series seems to be represented by conglomerates and coarse sandstones. In others, the Lower Coal-measures, or the Marine Limestones, or both, are extensively developed. These local differences are, on a small scale, of the same character with those which occur on a large scale in the Northern and Southern Appalachian districts and Western districts of the United States, and in the different coal-areas of Great Britain and Ireland, as compared with each other and with the Carboniferous districts of

America. On the whole, however, it is apparent that certain grand features of similarity can be traced in the distribution of the Carboniferous rocks throughout the northern hemisphere.

It is further to be observed that in Nova Scotia and New Brunswick, as well as in Eastern Canada, disturbances occurred at the close of the Devonian period which have caused the Carboniferous rocks to lie unconformably on those of the former; and that in like manner the Carboniferous period was followed by similar disturbances, which have thrown the Carboniferous beds into synclinal and anticlinal bends, often very abrupt, before the deposition of the Triassic Red Sandstones. These disturbances were of a different character from the oscillations of level which occurred within the Carboniferous period. They were accompanied by volcanic action, and were most intense along certain lines, and especially near the junction of the Carboniferous with the older formations.

I have noticed an apparent case of unconformability between members of the Carboniferous system near Antigonish*. In the county of Pictou the arrangement of the beds suggests a possible unconformability of the Upper Coal-formation and the Coal-measures†. In New Brunswick Prof. Bailey‡ has observed indications of local unconformability of the Coal-formation with the Lower Carboniferous. But the strict conformability of all the members of the Carboniferous series in the great majority of cases, shows that these instances of unconformability are exceptional. In the section at the Joggins, more especially, the whole series presents a regular dip, diminishing gradually from the margin to the middle line of the trough, where the beds become horizontal.

The most gradual and uniform oscillations of level must, however, be accompanied with irregularities of deposition and local denudation; and phenomena of this kind are abundantly manifest in the Carboniferous strata of Nova Scotia. I have described in 'Acadian Geology' a bed in the Pictou coal-field which seems to be an ancient shingle-beach, extending across a bay or indentation in the coast-line of the Carboniferous period§. At the Joggins many instances occur of the sudden running out and cutting off of beds ||, and Mr. Brown has figured a number of instances of this kind in the Coal-formation of Sydney¶. They are of such a character as to indicate the cutting action of tidal or fluviatile currents on the muddy or sandy bottom of shallow water. In some instances the layers of sand and drift-plants filling such cuts suggest the idea of tidal channels in an estuary filled with matter carried down by river-inundations. Even the beds of coal are by no means uniform when traced for considerable distances. The beds which have been mined at Pictou and the Joggins show material differences in quality and associations; and small beds may be observed to change in a remarkable manner, in

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* Quart. Journ. Geol. Soc. vol. i. p. 32.

† *Ibid.* vol. x. p. 42; Acadian Geology, p. 249.

‡ Report on Geology of Southern New Brunswick. p. 118.

§ Quart. Journ. Geol. Soc. vol. x. p. 45.

|| *Ibid.* vol. x. p. 12.

¶ *Ibid.* vol. vi. p. 125 *et seq.*

their thickness and in the materials associated with them, in tracing them a few hundreds of feet from the top of the cliff to low-water mark on the beach. I have no doubt that, could we trace them over sufficiently large areas, they would all be found to give place to sandstones, or to run out into bituminous shales and limestones, according to the undulations of the surfaces on which they were deposited, just as the peaty matter in modern swamps thins out toward banks of sand, or passes into the muck or mud of inundated flats or ponds.

3. *Geological Cycles.*—The foregoing considerations bring, in a very distinct manner, before us two different, and at first sight irreconcileable, general views which we may take of any given geological period. *First*, we must regard every such period as presenting during its whole continuance the diversified conditions of land and water with their appropriate inhabitants; and *secondly*, we must consider each such period as forming a geological cycle, in which such conditions to a certain extent were successive. As we give prominence to one or the other of these views, our conclusions as to the character of geological chronology must vary in their character; and in order to arrive at a true picture of any given time, it is necessary to have both before us in their due proportion.

We know that the marine animals of the Lower Carboniferous seas continued to exist in the time of the Coal-formation, and that some of them survived until the Permian period, proving to us the existence of deep seas even in that age which we regard as specially characterized by swampy flats supporting land-plants. In like manner we know that some of the species of land-plants found in the lowest Coal-measures continued to exist in the time of the Upper Coal-formation, proving that there was some land suitable for them throughout the epoch of the deep-sea limestones. Regarded from this point of view, any exceptional beds with land-plants in the marine parts of the formation, or beds with sea-shells in the parts where land-conditions predominate, acquire a special interest; and so likewise do regions in which, as in some parts of the Appalachian Coal-field, the marine limestones are absent, and those in which, as in some parts of the Western States, marine conditions seem to have continued throughout the whole period. In Nova Scotia, so far as my present knowledge extends, the marine limestones of the Lower Carboniferous cut off the flora of the Lower Coal-measures, apparently by a long interval of time, from that of the Middle Coal-formation; and in like manner the fossils of the marine limestones cease at the time of the Millstone-grit, and only in one instance, that of a small bed of limestone near Wallace Harbour, partially reappear in the Upper Coal-formation*. I have, however, ascertained that the Marine Limestones may be divided into an upper and a lower member, and that there is some reason to suppose that in some parts of Nova Scotia, where the true Coal-measures are not developed, the upper member may in part, at least, represent them†.

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* Acad. Geol. p. 183; Quart. Journ. Geol. Soc. vol. ii. p. 133.

† Quart. Journ. Geol. Soc. vol. xv. pp. 63 *et seq.* My friend Mr. C. F. Hartt, who

On the other hand, I have not as yet been able to bridge over the gulf which separates the flora of the Lower Carboniferous Coal-measures from that of the Middle Coal-formation, an interval which may include much of the "Lower Coal-measures" of Rogers in the Pennsylvania Coal-field.

Turning to that broader view which takes the prevalent conditions of each portion of the period as characteristic, notwithstanding the local existence of dissimilar conditions, we not only find, as already stated, that the sequence in Nova Scotia coincides generally with that in other parts of America and in Europe, but that, viewed in this aspect, the Carboniferous period constitutes one of four great physical cycles, which make up the Palæozoic age in Eastern America—and each of which was characterized by a great subsidence and partial re-elevation, succeeded by a second and very gradual subsidence. Viewed in this way, the Lower Carboniferous conglomerate and Lower Coal-measures correspond analogically with the Oriskany Sandstone, the Oneida and Medina Sandstones, and the Potsdam and Calciferous. The Carboniferous Limestone corresponds with the Corniferous Limestone, the Niagara Limestone, and the Trenton group of limestones. The Coal-measures correspond with the Hamilton group, the Salina group, and the Utica Shale. The Upper Coal-formation corresponds with the Chemung, the Lower Helderberg, and the Hudson-River groups. The Permian is not represented in Eastern America; but as developed in Europe it clearly constitutes a similar cycle. These parallelisms, which deserve more attention from geologists than they have yet received, may be tabulated thus*:—

Tabular View of Cycles in the Palæozoic Age in Eastern America.
(The several formations are arranged in descending order.)

Character of group.	Lower Silurian.	Upper Silurian.	Devonian.	Carboniferous.
Shallow, subsiding marine area, filling up with sediment	Hudson-River group.	Lower Helderberg group.	Chemung gr. . .	Upper Coal-formation.
Elevation, followed by slow subsidence, land-surfaces, &c.	Utica shale ..	Salina group. .	Hamilton gr. ..	Coal-measures.
Marine conditions: formation of limestones, &c. ..	Trenton, Black R. and Chazy limestones.	Niagara and Clinton limestones.	Corniferous limestone.	Lower Carboniferous limestone.
Subsidence; disturbances; deposition of coarse sediment	Potsdam and Calciferous sandstones.	Oneida and Medina sandstones.	Oriskany sandstone.	Lower Coal-measures and conglomerate.

In the Permian of Europe, the Stinkstein, the Rauchwacke, the Zechstein, and the Rothliegendes might form a fifth parallel column.

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has more recently studied the Marine Limestones, has obtained facts which seem to indicate the possibility of a more minute subdivision than any hitherto attempted of these beds.

* Dr. Sterry Hunt has directed attention to them in a paper "On Bitumens," 'Silliman's Journal' [2]. xxxv. p. 166, and in the 'Geology of Canada,' 1863, p. 627; and Dana refers to them in his 'Manual of Geology.' Eaton and Hall had previously noticed these parallelisms.

Of course such parallelism might be variously expressed by reckoning a smaller or larger number of groups. Independently of these different modes of statement, however, I believe that the basis of such comparisons exists in nature, and that it will prove possible to subdivide geological time into determinate natural cycles, the parts of which are analogous to those of similar cycles. A further question to be solved is, whether such cycles corresponded in all parts of the world, or whether, as is more likely, the earth might be divided into areas in which in each cycle elevation and subsidence were contemporaneous. So far as the present subject is concerned, I merely desire to show that the Carboniferous rocks of Nova Scotia represent a complete cycle of the earth's history, and correspond in time with the Carboniferous of Europe, and in value with the other great divisions of the Palæozoic age.

4. *Summary of facts relating to the mode of accumulation of Coal.*—With regard to the more special subject of this paper, I would rather invite attention to the details to be presented under the next head, than make any preliminary general statements. It is, however, necessary to notice here the several views which have prevailed as to the probable accumulation of coal by driftage or growth *in situ*, in water or on land. I have already, in previous publications*, stated very fully the conclusions at which I have arrived on some portions of this subject, and I would now sum up the more important general truths as follows:—(1) The occurrence of *Stigmaria* under nearly every bed of coal, proves beyond question that the material was accumulated by growth *in situ*, while the character of the sediments intervening between the beds of coal proves with equal certainty the abundant transport of mud and sand by water. In other words, conditions similar to those of the swampy deltas of great rivers are implied. (2) The true coal consists principally of the flattened bark of Sigillarioid and other trees, intermixed with leaves of ferns and *Cordaites*, and other herbaceous débris, and with fragments of decayed wood constituting "mineral charcoal," all these materials having manifestly alike grown and accumulated where we find them. (3) The microscopical structure and chemical composition of the beds of Cannel-coal and earthy bitumen, and of the more highly bituminous and carbonaceous shales, show them to have been of the nature of the fine vegetable mud which accumulates in the ponds and shallow lakes of modern swamps. When such fine vegetable sediment is mixed, as is often the case, with shales, it becomes similar to the bituminous limestone and calcareo-bituminous shales of the Coal-measures. (4) A few of the underclays which support beds of coal are of the nature of the vegetable mud above referred to; but the greater part are argillo-arenaceous in composition, with little vegetable matter, and bleached by the drainage from them of water containing the products of vegetable decay. They are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage. The absence of sul-

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* "On the Structures of Coal," Quart. Journ. Geol. Soc. vol. xv. Air-breathers of the Coal Period, Montreal, 1863, p. 18.

phurets, and the occurrence of carbonate of iron in connexion with them, prove that, when they existed as soils, rain-water, and not sea-water, percolated them. (5) The coal and the fossil forests present many evidences of subaërial conditions. Most of the erect and prostrate trees had become hollow shells of bark before they were finally imbedded, and their wood had broken into cubical pieces of mineral charcoal. Land-snails and galley-worms (*Xylobius*) crept into them, and they became dens or traps for reptiles. Large quantities of mineral charcoal occur on the surfaces of all the larger beds of coal. None of these appearances could have been produced by subaqueous action. (6) Though the roots of *Sigillaria* bear some resemblance to the rhizomes of certain aquatic plants, yet structurally they are absolutely identical with the roots of Cycads, which the stems also resemble. Further, the *Sigillariæ* grew on the same soils which supported Conifers, *Lepidodendra*, *Cordaites*, and Ferns, plants which could not have grown in water. Again, with the exception, perhaps, of some *Pinnulariæ* and *Asterophyllites*, there is a remarkable absence from the Coal-measures of any form of properly aquatic vegetation. (7) The occurrence of marine or brackish-water animals in the roofs of coal-beds, or even in the coal itself, affords no evidence of subaqueous accumulation, since the same thing occurs in the case of modern submarine forests. For these and other reasons, some of which are more fully stated in the papers already referred to, while I admit that the areas of coal-accumulation were frequently submerged, I must maintain that the true coal is a subaërial accumulation by vegetable growth on soils wet and swampy, it is true, but not submerged. I would add the further consideration, already urged elsewhere, that, in the case of the fossil forests associated with the coal, the conditions of submergence and silting-up which have preserved the trees as fossils must have been precisely those which were fatal to their existence as living plants—a fact sufficiently evident to us in the case of modern submarine forests, but often overlooked by the framers of theories of the accumulation of coal.

It seems strange that the occasional inequalities of the floors of the coal-beds, the sand or gravel ridges which traverse them, the channels cut through the coal, the occurrence of patches of sand, and the insertion of wedges of such material splitting the beds, have been regarded by some able geologists as evidences of the aqueous origin of coal. In truth, these appearances are of constant occurrence in modern swamps and marshes, more especially near their margins, or where they are exposed to the effects of ocean-storms or river-inundations. The lamination of the coal has also been adduced as a proof of aqueous deposition; but the microscope shows, as I have elsewhere pointed out, that this is entirely different from aqueous lamination, and depends on the superposition of successive generations of more or less decayed trunks of trees and beds of leaves. The lamination in the truly aqueous cannels and carbonaceous shales is of a very different character.

It is scarcely necessary to remark that in the above summary I have had reference principally to the appearances presented by the Coal-formation of Nova Scotia, and that I have no wish to undervalue the admirable researches on this subject of Brongniart, Goeppert, Hawkshaw, Beaumont, Binney, Rogers, Lesquereux, and others, whose publications on this subject I have read with interest, and have tested in their application to the phenomena presented to me in the coal-fields of Nova Scotia. I may add that in my opinion the phenomena of the Stigmaria-underclays, to which attention was first directed by Sir W. E. Logan, furnish the key to the whole question of the origin of coal, and that the comparisons of Coal-deposits, by Sir Charles Lyell, with the "Cypress-swamps" of tho Mississippi perfectly explain all the more important appearances in the Coal-formation of Nova Scotia.

§ III. Details of the Character and Fossil Contents of the several Beds of Coal, as exposed in the South Joggins Section.

1. *Introduction.*—Under this heading I propose to state all the facts bearing on the origin and mode of formation of the several coals, obtained either by careful study of their outcrops on the ground, or by subsequent examination, with the aid of the microscope, of specimens collected from them. I shall follow the order of the detailed section published by Sir W. E. Logan in 1845*, including the additional points observed by Sir C. Lyell and myself in 1852, and by myself in several successive visits†, but giving in minute detail only the coals and their associated roof-beds and underclays. The sandstones and shales which constitute the mechanical filling-in between the beds of coal I shall group together in the shortest possible manner, referring to the published sections above-mentioned for details. I shall, however, mention every case of the occurrence of beds holding erect trees, and of Stigmarian underclays, as well as of beds of bituminous limestone and highly carbonaceous shale. I regard the former as being truly land-surfaces, as well as the coals, and the latter as accumulations of vegetable mud or muck which imply the contemporaneous existence in their vicinity of swamps and forests.

2. *Logan's Section* (order descending). a. *Division* 1.—This extends along the coast from Shoulie River to the vicinity of Ragged Reef, being nearly horizontal at the former place and gradually assuming a decided south-west dip towards the latter. It is 1617 feet in vertical thickness, and constitutes the upper part of the "Upper Coal-formation." It occupies the centre of the great synclinal of the western part of the Cumberland coal-area, and presents the newest beds of the Carboniferous system.

The rocks are thick-bedded white and grey sandstones, passing in some places into conglomerates with quartz pebbles, and interstratified with reddish and chocolate shales. The sandstones predominate.

Fossils are not numerous in these beds. Those found are *Dadoxy-*

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* Report of Progress of Canadian Survey, 1845.

† Quart. Journ. Geol. Soc. vol. x.; also Acadian Geology, p. 128 *et seq.*

lon materiarium, of which there are many drifted trunks in the sandstones in a blackened and calcified condition, *Calamites Suckovii*, *C. Cistii*, *Calamodendron approximatum*, *Lepidodendron undulatum*, *Lepidophloios parvus*, and *Stigmaria ficoides*. As in the Upper Coal-formation of Pictou, trunks of Conifers and Calamites are the most abundant fossils.

b. *Division* 2.—This occurs at Ragged Reef and its vicinity. Its thickness is 650 feet. It constitutes the lower part of the Upper Coal-formation.

The rocks are white and grey sandstones with occasional reddish beds, and red and grey shales. The sandstones and shales are nearly in equal proportions. Underclays, or soils supporting erect plants, probably *Sigillariæ*, occur at two levels.

Fossils are not numerous. Those collected were *Sigillaria scutellata* and *Stigmaria ficoides*, *Calamites Suckovii*, *Sphenopteris hymenophylloides*, *Alethopteris lonchitica*, *Cyclopteris heterophylla* (?), *Beinertia Gœpperti*, and portions of the strobiles of two species of *Lepidophloios*, namely *Lepidophyllum lanceolatum* and *L. trinerve*.

c. *Division* 3.—This extends in descending order from the vicinity of Ragged Reef to McCairn's Brook. Its thickness is 2134 feet. It includes the upper part of the "Middle Coal-formation," and is perhaps equivalent, in part at least, to the Upper Coal-measures of Great Britain, and to the Upper Coal-formation of American authors.

It includes 1009 feet of sandstone, almost all of which is grey, and 912 feet of grey and reddish shale and clay. It contains 22 beds of coal, all of small thickness, and most of them of coarse quality. Below I give each bed of coal in detail, with its roof and floor and its fossils; and the intervening mechanical beds in brackets. The thickness of the roofs and floors is included in that stated for the intervening beds.

		ft.	in.
	(Carbonaceous shale, grey understone, with *Stigmaria* and grey shale)	7	0
Coal-group 1	Grey argillaceous shale. *Coal* 1 inch Grey argillaceous underclay, *Stigmaria*.	0	1

The roof holds abundance of *Alethopteris lonchitica*. The coal is coarse and earthy, with much epidermal and bast tissue*, vascular bundles of ferns, and impressions of *Sigillaria* and *Cordaites*. It is a compressed vegetable soil or dirt-bed, resting on an argillaceous subsoil with rootlets of *Stigmaria*.

		ft.	in.
	(Grey and reddish sandstones and grey and red shales with ironstone nodules)	281	6
Coal-group 2	Reddish argillaceous shale. *Coal* 1 inch Carbonaceous shale 4 inches *Coal* 1 inch Reddish underclay, *Stigmaria*.	0	6

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* For explanation as to the nature of these and other structures in the coal, see under § IV., below.

The coal is coarse, earthy, and shaly. It contains *Cordaites*, fern stipes, and bast tissue.

		ft.	in.
	(Reddish shale and grey sandstone, the latter seen in the cliff to thin out and give place to reddish shale)	53	9
Coal-group 3 ...	Grey sandstone.		
	Coal 1 inch....	0	1
	Grey and reddish sandy understone, *Stigmaria*.		

The coal is coarse and shaly. No fossils were observed, except stumps and rootlets of *Stigmaria* in the underclay.

	(Reddish grey shale and grey sandstone)	6	0
Coal-group 4 ...	Reddish grey shale.		
	Coal 2 inches	0	2
	Grey and reddish argillaceous underclay, *Stigmaria*.		

The coal is coarse and earthy. No fossils were observed, except *Stigmaria* rootlets in the underclay. This and the last coal are to be regarded merely as fossil vegetable soils or dirt-beds.

	(Grey sandstone and grey and reddish shale. One underclay, and erect *Calamites* in the lowest bed)	239	6
Coal-group 5 ...	Grey argillaceous shale.		
	Coal 2 inches	0	2
	Grey argillo-arenaceous underclay, *Stigmaria*.		

The coal is filled with leaves of *Cordaites borassifolia*, dividing it into thin papery layers. The underclay has many large branching roots of *Stigmaria*.

	(Grey shale and sandstone)	19	0
Coal-group 6 ...	Grey arenaceous shale.		
	Coal 3 inches	0	3
	Grey argillo-arenaceous underclay, *Stigmaria*.		

This coal is composed of flattened bark of *Sigillaria*, of which there are many layers in the thickness of the bed. The species are not distinguishable.

	(Grey sandstone and shale. One underclay with *Stigmaria*)	12	6
Coal-group 7 ...	Grey argillaceous shale.		
	Coal 1 inch.		
	Grey argillacous underclay, *Stigmaria*, 1 ft. 6 in.		
	Coal 2 inches.		
	Grey argillaceous underclay, *Stigmaria*, 4 inches.		
	Coal 1 inch.		
	Grey argillaceous underclay, *Stigmaria*	2	2

This is an alternation of thin coarse coals or fossil vegetable soils with *Stigmaria* subsoils. The roof-shale contains erect *Calamites*, which seem to have been the last vegetation which grew on the surface of the upper coal.

	(Grey and reddish sandstones and shales)	73	0
Coal-group 8 ...	Red and grey shale.		
	Coal 1 inch	0	1
	Grey hard underclay, *Stigmaria*.		

This coal contains flattened trunks of *Sigillaria scutellata*, or an allied species, and of other *Sigillariæ*, also abundance of vascular bundles of ferns and portions of epidermal tissues of different plants.

		ft.	in.
	(Grey sandstone and red and grey shales. *Stigmaria* in the upper bed, and prostrate *Sigillaria* and *Cordaites* in some of the sandstones and shales)...	490	0
Coal-group 9 ...	Grey argillaceous shale, ironstone nodules.		
	Coal 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof of this coal holds prostrate *Sigillariæ* of three species and *Cordaites borassifolia*. The coal is hard and shining, with impressions of flattened *Sigillariæ*, also of *Cordaites*, *Asterophyllites*, *Carpolites*, and vascular bundles of ferns.

	(Underclay and reddish grey shale)	6	0
Coal-group 10...	Reddish grey shale.		
	Coal and coaly shale 8 inches.		
	Grey argillaceous underclay, nodules of ironstone, and *Stigmaria* 2 feet.		
	Coal, stony and compact, 2 inches	2	10
	Grey argillaceous underclay, *Stigmaria*.		

The roof-shale has obscure impressions of plants, apparently petioles of ferns. The upper coal is thinly laminated and full of leaves of *Cordaites* and ferns, among which is *Alethopteris lonchitica*. The lower coal is compact, resembling cannel, and has many vascular bundles of ferns. It seems to be composed of herbaceous matter macerated in water and mixed with mud.

	(Grey sandstone and shale with nodules of ironstone)	23	0
Coal-group 11...	Grey argillaceous shale.		
	Coal, shaly, 3 inches	0	3
	Arenaceous underclay, *Stigmaria*.		

An erect ribbed *Sigillaria* appears in the roof-shale. The coal contains many flattened *Sigillariæ*, also *Trigonocarpa*, *Cordaites*, and vascular bundles of ferns.

	(Arenaceous understone with ironstone nodules and *Stigmaria*, and carbonaceous shale)............	7	9
Coal-group 12...	Carbonaceous shale.		
	Coal 2 inches	0	2
	Argillaceous underclay, ironstone, and *Stigmaria*.		

This coal is hard and laminated, with many vascular bundles of ferns upon its surfaces.

	(Grey sandstone and grey argillaceous shale)............	12	0
Coal-group 13...	Grey argillaceous shale.		
	Coal 7 inches	0	7
	Grey argillaceous underclay, ironstone, and *Stigmaria*.		

The roof contains erect stumps, not distinctly marked. The coal has indications of bark of *Sigillaria*, and is hard and shining, with a coarse earthy layer in the middle.

	(Grey shale)	7	0
Coal-group 14...	Grey shale, as above.		
	Coal 4 inches	0	4

		ft.	in.
Coal-group 14...	Grey argillo-arenaceous underclay, ironstone, and *Stigmaria*	1	6
	Coal 2 inches	0	2
	Grey argillaceous underclay, ironstone, and *Stigmaria*.		

The upper coal has impressions of bark of trees and *Cordaites*, especially in its upper part.

	(Grey and reddish shale and grey sandstone, with Stigmarian soils at two levels)	52	0
Coal-group 15...	Grey shale.		
	Carbonaceous shale 2 inches.		
	Argillaceous underclay, ironstone, and *Stigmaria*...	1	0
	Coal 1 inch	0	3
	Argillaceous underclay, ironstone, and *Stigmaria*....		

The upper shaly bed is a coal interlaminated with shale, which enables the nature of the coaly matter to be ascertained. It contains flattened *Sigillariæ* of several species, *Calamites, Cordaites, Cyperites,* leaves of *Sigillaria,* and *Lepidophylla*. The clay parting is the roof of the lower coal, and contains *Cyperites* and *Cordaites.* It has been converted into an underclay by the growth of *Sigillaria* upon it in the formation of the upper bed of coaly shale. The lower coal is compact, but showed an impression of a Calamite.

	(Grey sandstone and grey and reddish shale, ironstone nodules)	16	0
Coal-group 16...	Grey argillaceous shale.		
	Coal and carbonaceous shale 2 inches	0	2
	Reddish argillaceous underclay, ironstone, and *Stigmaria*.		

The roof supports an erect tree, a *Sigillaria* 8 feet high and 1 foot in diameter. It is also rich in *Cyperites**, *Cordaites*, and *Calamites*. The coal contains *Calamites* and and also discigerous tissue of Conifers or *Sigillaria*.

	(Grey sandstones and reddish and grey shales, with several Stigmarian underclays and coaly films or thin vegetable soils. One of the underclays supports large stumps of *Sigillaria*, with *Cyperites*, *Cordaites*, and *Lepidodendron* in the bed around their bases)	38	6
Coal-group 17...	Red and grey argillaceous shale.		
	Coal 1 inch.		
	Gray argillo-arenaceous underclay, *Stigmaria*, 4 ft.		
	Coal 4 inches.		
	Carbonaceous shale 4 inches.		
	Coal 1 inch	4	10
	Grey arenaceous underclay, *Stigmaria*.		

The upper layer of coal consists in part of leaves of *Cordaites*. The middle layer has much *Cordaites* and *Cyperites*.

	(Underclay and grey shale)	2	3
Coal-group 18...	Grey shale, as above.		
	Coal 3 inches	0	3
	Grey arenaceous underclay, *Stigmaria*.		

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* By this term I continue, for convenience, to designate the leaves of *Sigillariæ*.

		ft.	in.
	(Grey sandstone, and red and grey shale. Stigmarian soils at two levels)	26	0
Coal-group 19...	Reddish shale.		
	Coal 1 inch	0	1
	Red argillaceous underclay, *Stigmaria*.		

The roof contains an erect *Sigillaria*. The coal and that of the previous bed were not well seen.

		ft.	in.
	(Grey sandstone and red and grey shales, with many drift-trunks and erect *Sigillariæ* at four levels)...	222	0
Coal-group 20...	Grey shale.		
	Coal 1 inch	0	1
	Red and grey underclay, *Stigmaria*	36	0

This coal contains much *Cordaites*.

		ft.	in.
	(Grey and red shales and grey sandstone. One Stigmarian soil, and resting on it carbonaceous shale with *Cyperites*)	16	3
Coal-group 20a*	Grey shale.		
	Coal 2 inches.		
	Underclay, *Stigmaria*, 2 inches.		
	Coal 1 inch.		
	Underclay 1 inch, *Stigmaria*.		
	Coal 3 inches	0	9
	Argillaceous underclay, ironstone, and *Stigmaria*.		

These coals contain mineral charcoal, showing scalariform and epidermal tissues. The coals are impure, and were probably concealed at the time of Sir W. E. Logan's visit.

		ft.	in.
	(Sandstone and red and grey shale, with one Stigmarian soil)	93	3
Coal-group 21...	Red shale.		
	Coal and carbonaceous shale, 2 inches	0	2
	Grey argillaceous underclay, *Stigmaria*.		

In the bed above the roof-shale are erect *Calamites*. The coal is an uneven or irregular bed, and consists of flattened *Sigillariæ*, *Cyperites*, *Cordaites*, and ferns.

		ft.	in.
	(Grey and reddish sandstones and shales, with drift-trunks of *Dadoxylon materiarium*, *Sigillaria*, and *Calamites*)	334	0
Coal-group 22...	Grey and red shale, nodules of ironstone.		
	Coal and carbonaceous shale, 2 inches	0	2
	Grey argillo-arenaceous underclay, *Stigmaria*.		

This coal consists of flattened bark of *Sigillaria* with *Cordaites*, and vascular bundles of ferns. It contains also remains of fishes. Among these was found a tooth of *Ctenoptychius*. The underclay includes stumps of *Stigmaria*, as well as rootlets.

		ft.	in.
	(Grey sandstone and shale with one Stigmarian soil supporting erect stumps of *Sigillaria*)	68	0
Total thickness of Division 3, according to Logan's measurements		2159	8

d. *Division* 4.—This division of the section extends from McCairn's Cove to the end of the high cliff beyond "Coal-mine Point." It corresponds to the lower part of the Middle Coal-formation, and probably to the Lower Coal-formation of some American authors. Its thickness, according to the measurements of Sir William E. Logan, is 2539 feet. It is remarkable for the prevalence of grey sandstones and grey and dark-coloured shales. It constitutes the part of the section re-examined by Sir C. Lyell and myself in 1852; and in the memoir which I subsequently published it is divided into 27 groups or subdivisions. For facility of reference these groups are indicated by the Roman numerals in the following pages, beginning with the highest group, XXVII.

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* I designate in this way coal-groups not noticed in Logan's section.

XXVII.

		ft.	in.
Coal-group 1 ...	Bituminous limestone and calcareo-bituminous shale 4 feet.		
	Coal 1 foot	5	0
	Grey argillo-arenaceous underclay, *Stigmaria*.		

The roof has *Naiadites carbonarius* and *N. elongatus*, *Spirorbis carbonarius*, scales of *Rhizodus*, and obscure vegetable fragments. The coal contains flattened *Sigillariæ*, *Cordaites*, *Alethopteris lonchitica*, *Cyperites*, *Calamites Nova-scotica*, and many vascular bundles of ferns.

		ft.	in.
	(Grey sandstone and shale with six underclays and erect *Sigillaria* at two levels; also a thin shale with *Naiadites*, *Cythere*, *Calamites*, and *Cordaites*. One of the sandstones has scales and teeth of a large fish (? *Rhizodus*) and plants covered with *Spirorbis*)	50	0
Coal-group 2 ...	Grey argillaceous shale.		
	Coal 1 inch.		
	Clay 3 inches.		
	Coal 1 inch.		
	Clay 1 inch.		
	Coal 1 inch.		
	Shale 4 inches.		
	Coal 3 inches	1	2
	Grey argillo-arenaceous underclay, *Stigmaria*.		

The roof has numerous vegetable fragments and flattened *Sigillariæ* and *Calamites*. One of the coals contains mineral charcoal, showing bast tissue, scalariform tissue, and fragments of epidermis. The lower coal has bark of *Sigillaria*, *Stigmaria*, and *Cyperites*, also numerous *Trigonocarpa* and vascular bundles of ferns. The clay partings and the underclay have obscure rootlets, probably of *Stigmaria*.

		ft.	in.
	(Arenaceous underclay and shale with remains of *Stigmaria*.)		
Coal-group 3 ...	Grey argillaceous shale.		
	Coal 3 inches	0	3
	Hard argillo-arenaceous underclay, *Stigmaria*.		

The roof has stumps of *Sigillariæ*, erect and with roots of *Stigmaria* descending among them from the bed above. The coal, which is coarse and earthy, has vascular bundles of ferns, scalariform vessels, bast tissue, and scales and spines of fishes (*Palæoniscus*, &c.), with coprolitic matter. The underclay shows abundant Stigmarian rootlets.

		ft.	in.
	(Underclay and grey arenaceous shale)	6	0
Coal-group 4 ...	Grey argillaceous shale. *Coal* 9 inches. Carbonaceous shale 6 inches. *Coal* 1 inch. Carbonaceous shale 4 inches. *Coal* 1 inch. Carbonaceous shale 8 inches. *Coal* 2 inches. Grey shale 1 foot 7 inches. *Coal* 8 inches Argillo-arenaceous underclay, *Stigmaria*.	4	10

The roof contains obscure flattened plants. The coal is hard or shaly, with vascular bundles of ferns and bast tissue. The carbonaceous shales yield *Cordaites borassifolia*, *Alethopteris lonchitica*, *Calamites*, *Sigillaria*, and *Cyperites*. The grey shale parting has erect stumps, apparently of *Sigillaria*. The upper shales and coals are very pyritous, and decompose when exposed to the weather—an indication that sea-water had access to these beds while the vegetable matter was still recent.

XXVI.

		ft.	in.
	(Grey argillaceous sandstone and red and grey shale, with two Stigmarian soils. Footprints, probably of *Dendrerpeton*, and rain-marks occur in these beds: and it was in one of them that Mr. Marsh discovered the vertebræ of *Eosaurus Acadianus*)	82	0

XXV.

		ft.	in.
Coal-group 5 ...	Bituminous limestone 2 feet. *Coal* ½ inch. Argillo-arenaceous clay, *Stigmaria*, 6 inches. *Coaly shale* ½ inch. Grey argillo-arenaceous shale, ironstone nodules, *Stigmaria*, 1 foot 6 inches. *Coaly shale* 1 inch. Grey shale, ironstone nodules, *Stigmaria*, 2 ft. 6 in. *Coal* 6 inches Argillo-arenaceous underclay, *Stigmaria*.	7	2

The bituminous limestone of the roof contains *Naiadites carbonarius* and *N. elongatus*, fish-scales, and Cyprids. The upper layer of coal contains impressions of *Sigillaria* and *Lepidodendron*, on some of which are shells of *Spirorbis*. It has epidermal tissues, vascular bundles of ferns, and reticulated vessels. The coaly shales are of the nature of coarse coals, but with numerous thin layers of shaly matter. The lower coal contains petioles of ferns and *Cordaites* matted together, and numerous *Cardiocarpa*. The two thick clay partings and the underclay are Stigmarian soils.

XXIV.

		ft.	in.
	(Grey sandstone and chocolate and grey shales, with two Stigmarian soils)	147	0

XXIII.

		ft.	in.
Coal-group 6 ...	Carbonaceous shale, passing downward into bituminous limestone, 1 foot 10 inches.		
	Coal 4 inches	2	2
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof contains *Naiadites carbonarius*, *Cythere*, *Spirorbis*, fish-scales, and coprolites. The coal is hard and laminated, and has on its surfaces leaves of *Cordaites* and vascular bundles of ferns. It is remarkable for containing scattered remains of a number of species of fishes, belonging to the genera *Ctenoptychius*, *Diplodus*, *Palæoniscus*, and *Rhizodus*. The underclay has rootlets of *Stigmaria*, and the bed below this has large roots of the same.

		ft.	in.
	(Grey sandstone and shale, the latter with nodules of ironstone. Erect trees at one level)	30	0
Coal-group 7 ...	Grey sandstone.		
	Coal 10 inches.		
	Carbonaceous shale 2 inches		
	Coal 10 inches.		
	Carbonaceous shale 2 inches.		
	Coal and coaly shale 2 feet 6 inches.....................	4	6
	Grey argillo-arenaceous underclay, *Stigmaria*.		

This is the bed worked at the Joggins as the "Main Seam;" and I believe that it improves somewhat in mining it inward from the shore. The roof has afforded *Sigillaria catenoides* and other species, *Alethopteris lonchitica*, *Cordaites borassifolia*, *Lepidodendron elegans*, *Trigonocarpa*, *Naiadites*, *Spirorbis*, *Cythere*, fragments of insects (?). The mineral charcoal contains bast tissue, scalariform, epidermal, and cellular tissues. In the compact part of the coal there is dense cellular and epidermal tissue. The roof is especially rich in *Cordaites*, sometimes with *Spirorbis* adherent.

		ft.	in.
	(Grey sandstone and shale, with many ironstone nodules in the shale, and erect *Sigillaria* and underclays at five levels. One of the latter has large stumps of *Stigmaria* and a thin coaly layer resting on it)	68	0
Coal-group 8 ...	Grey shale with nodules of ironstone.		
	Coal 2 inches.		
	Grey shale 4 inches.		
	Coal 3 inches.		
	Carbonaceous shale 1 foot 3 inches.		
	Coal 1 inch.		
	Argillaceous shale, ironstone nodules, 4 feet.		
	Coal 1 foot..	7	1
	Grey argillo-arenaceous underclay, ironstone nodules, and *Stigmaria*.		

The roofs of the first and second beds in this group are among the richest in fossils in the Joggins section. They have afforded *Pecopteris lonchitica*, *Cyclopteris*, *Cyperites*, *Cordaites borassifolia*, *Cardiocarpum fluitans*, *Sigillaria elegans*, *Lepidophloios Acadianus*, *Lepidodendron undulatum*, ft. in.

Pinnularia, *Trigonocarpa*, &c.; also *Diplostylus Dawsoni**, *Eurypterus*, *Cythere*, *Naiadites*, and *Spirorbis* attached to plants. The lower coal, called locally the "Queen's Vein," has in its mineral charcoal bast cells, uniporous, rariporous, and multiporous wood-cells, scalariform vessels, epidermal tissue, and vascular bundles of ferns, also stipes of ferns and bark of *Sigillaria*. The mineral charcoal occurs principally in a thick layer near the bottom of the bed. Its roof has trunks of *Lepidophloios*, *Lepidodendron*, and *Sigillaria*, fossilized by carbonate of iron. The upper part of the lowest underclay is dark and carbonaceous, with Stigmarian rootlets.

XXII.

	(Grey sandstones, grey and chocolate shales with ironstone nodules; three underclays and erect *Calamites* and *Sigillaria* in three beds)	110	0

XXI.

Coal-group 9 ...	Grey shale and ironstone nodules.		
	Coal and coaly shale 1 foot 3 inches	1	3
	Argillaceous underclay, *Stigmaria*.		

The roof contains erect *Sigillariæ*, *Stigmaria*, *Calamites*, and *Cordaites*. The coaly shale has fern-stipes and *Cordaites*. The coal itself is coarse and shaly, and has a layer of mineral charcoal containing bast and epidermal tissue. There are also in the coal remains of *Calamites* and *Cordaites*, and fragments, possibly, of insects.

	(Grey and reddish shales with nodules of clay-ironstone, and grey and reddish sandstone. One underclay supporting a coaly film, and erect trees at two levels)	28	6
Coal-group 10...	Chocolate shale.		
	Coal and coaly shale 2 inches.		
	Coaly shale 6 inches.		
	Coal 4 inches	1	0
	Argillo-arenaceous underclay, *Stigmaria*.		

The upper coal contains flattened *Sigillariæ* and *Stigmaria*. The lower bed is hard and unequal, with curved laminæ and obscure traces of petioles of ferns. The mineral charcoal has bast and scalariform tissues.

XX.

	(Red and grey shales and grey sandstones. Erect *Calamites* in one bed. Four underclays)	78	6

XIX.

Coal-group 11...	Chocolate shale.		
	Coal and coaly shale 8 inches	0	8
	Argillaceous underclay, *Stigmaria*.		

The roof has *Cordaites*, *Calamites*, and rootlets. The coal contains much mineral charcoal with the structure of dense aporous bast tissue; it also contains *Cyperites* and many vascular bundles of ferns.

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* Salter, Quart. Journ. Geol. Soc. vol. xix. p. 77.

		ft.	in.
	(Grey sandstones and argillaceous shale. Erect trees at two levels)	37	0
Coal-group 12...	Grey shale. Coal and coaly shale 1 foot Argillaceous underclay, ironstone, and *Stigmaria*.	1	0

The roof contains erect *Sigillaria* and *Calamites*, also *Cordaites* with *Spirorbis* attached, and *Lepidodendron*. The coal has in one layer much *Cordaites*, in others it includes an immense number of specimens of *Sporangites papillata*; it has also bast tissue, epidermal tissue, and discigerous tissue.

	(Shale and sandstone, penetrated by Stigmarian rootlets, and containing in one of the shales *Lepidodendron*, *Sigillaria*, and *Carpolithes*)	13	0
Coal-group 13...	Grey shale. *Coal* and coaly shale Argillaceous underclay, *Stigmaria*.	0	6

The roof has much *Cordaites*. The shaly portions of the coal contain *Sigillaria elegans*, *Alethopteris lonchitica*, *Cordaites borassifolia*, *Lepidodendron*, *Diplotegium*, *Trigonocarpum*, *Stigmaria*, and *Sporangites glabra*, also vascular bundles of ferns and bast tissue.

XVIII.

	(Grey and red shales and grey sandstone; one of the latter with erect *Calamites* and *Sigillariæ*. One underclay)	69	4

XVII.

Coal-group 13*a*.	Grey shale. *Coal* 8 inches Argillaceous underclay, *Stigmaria*.	0	8

The roof has *Cordaites* and many decayed stipes. The coal has *Cordaites* and vegetable fragments.

XVI.

	(A very thick sandstone with shales. Erect *Calamites*, footprints of reptiles, and rain-marks)	57	0

XV.

Coal-group 14...	Grey shales with ironstone. *Coal* 3 inches. Coaly shale 2 inches. *Coal* 3 inches. Underclay, *Stigmaria*, 6 feet. Coaly shale 4 inches. Underclay, *Stigmaria*, 1 foot. Coaly shale 8 inches. Coal 2 inches Argillo-arenaceous underclay, *Stigmaria*, and ironstone.	8	10

On the roof of the upper coal is a fine-ribbed *Sigillaria* with Stigmarian roots. In the roof and shaly partings are *Sigillaria Brownii*, *S. Schlotheimiana*, and other species, *Stigmaria*, *Lepidodendron*, *Calamites*, *Cordaites*, *Sporangites glabra*, *Alethopteris lonchitica*, *Sphenopteris latifolia*, *Pinnularia*, and *Cyperites*; also *Cythere*, *Naiadites*, and fragments of reptilian (?) bones. The coal is pyritous, and exhibits impressions of the bark of *Sigillaria*; it contains also bast tissue, scalariform tissue of *Sigillaria*, and multiporous tissue of *Sigillaria* and *Calamodendron*.

		ft.	in.
	(Sandstone and shale, erect *Calamites* and *Sigillaria* with *Stigmaria*. The erect trees contain reptilian remains of the genera *Dendrerpeton*, *Hylonomus*, and *Hylerpeton*; also *Pupa vetusta*, *Xylobius Sigillariæ*, and remains of insects)	10	0
Coal-group 15...	Coaly shale.		
	Coal 6 inches	0	6
	Arenaceous underclay, *Stigmaria*.		

The erect trees above mentioned are rooted in the roof of this coal. It contains *Cyperites*, *Lepidophylla*, *Trigonocarpa* of 2 species, *Sphenophyllum*, *Alethopteris lonchitica*, *Cordaites*, and *Asterophyllites*. There are shells of *Spirorbis* on some of the plants. The coal contains layers of bark of *Sigillaria* and leaves of *Cordaites*, and much bast tissue, with scalariform, uniporous, and reticulated tissues, probably of *Sigillaria*.

		ft.	in.
	(Sandstones and shales; erect *Calamites* and *Stigmaria*)	21	0
Coal-group 15*a* .	Grey shale.		
	Coal 4 inches	0	4
	Argillaceous underclay, *Stigmaria*.		

The roof contains *Calamites*, *Sigillaria*, *Alethopteris lonchitica*, *Pinnularia*, *Lepidodendron*, *Cyperites*, *Sporangites*, and *Spirorbis*. One *Sigillaria* extends 30 feet without branching. The roof supports an erect tree. The coal is filled with flattened stems of *Sigillaria* lying in different directions, also flattened *Lepidodendra*; and in its mineral charcoal it has beautiful porous and scalariform tissues.

XIV.

		ft.	in.
	(Grey sandstone and grey and red shales. Many prostrate trunks of *Sigillaria* and *Lepidodendron*, one underclay, and erect trees at one level)	68	0
Coal-group 16...	Shale with the aspect of underclay.		
	Coal and coaly shale 6 inches	0	6
	Argillo-arenaceous underclay, ironstone, and *Stigmaria*.		

This bed was not well exposed, and afforded no fossils.

		ft.	in.
	(Grey sandstone and shale with one underclay)	25	6
Coal-group 17...	Grey shale.		
	Coal and coaly shale 3 inches	0	3
	Argillo-arenaceous underclay, *Stigmaria*.		

The roof has vegetable fragments and *Cordaites*. The coal is hard and coarse, and contains flattened broad-ribbed *Sigillaria*, *Cordaites*, and vascular bundles of ferns.

		ft.	in.
	(Shale and sandstone, erect trees at one level)	31	3

XIII.

		ft.	in.
Coal-group 18...	Grey shale. *Coal* 8 inches .... Argillo-arenaceous underclay.	0	8

The roof has an erect *Sigillaria*. The coal is shaly and laminated. It contains much *Cordaites*, also *Lepidodendron*, *Calamites*, and *Alethopteris lonchitica*. In one layer there are *Naiadites*, *Spirorbis*, and scales of fishes.

		ft.	in.
	(Grey sandstone and shale in several beds, *Stigmaria*)..	29	0
Coal-group 19...	Argillaceous shale. Coaly shale 4 feet. Bituminous limestone 2 feet 6 inches. Coal 1 inch..	6	7

The roof has *Naiadites*, scales and teeth of fishes, *Cythere*, and *Spirorbis*. The coal is hard and coarse, with vascular bundles of ferns and prostrate *Sigillariæ*.

		ft.	in.
	(Shale and sandstone)	20	6
Coal-group 20...	Coaly shale 1 foot. Bituminous limestone 1 foot 6 inches. *Coal* and clay partings 2 feet 4 inches..................	4	10

The roof has *Naiadites*, *Spirorbis* attached to plants, and small rhombic fish-scales. The coal alternates with limestone at the top, and contains remains of *Sigillaria*, *Sporangites*, and vascular bundles of ferns.

		ft.	in.
	(Sandstone, and grey and black shale with coaly layers)..	21	0
Coal-group 21...	Grey shale and calcareo-bituminous shale. *Coal* 10 inches .... Argillaceous underclay, *Stigmaria*.	0	10

The roof has obscure vegetable fragments and *Naiadites*. The coal contains vascular bundles of ferns, bast tissue, uniporous cells, and scalariform and reticulated vessels.

		ft.	in.
	(Grey sandstone and shale. Two underclays).........	20	0
Coal-group 22...	Grey shale. Coal and coaly shale 2 inches .... Argillaceous underclay, *Stigmaria*.	0	2

This bed was not well exposed.

		ft.	in.
	(Sandstone and shale, with one erect tree and two underclays)..	12	0
Coal-group 23...	Coaly and grey shale. *Coal* and coaly shale 4 inches. Bituminous limestone 4 inches. *Coal* and coaly shale 7 inches .... Argillo-arenaceous underclay, *Stigmaria*.	1	3

The roof has an erect tree, also *Cordaites* and *Spirorbis*. The shale and bituminous limestone contain *Sigillaria* and

Lepidophloios, also many large-furrowed trunks, probably old *Sigillariæ* or *Lepidodendra*.

XII.

		ft.	in.
	(Sandstone, shale, and calcareo-bituminous shale with three underclays)	26	0
Coal-group 24...	Calcareo-bituminous shale. *Coal* and coaly shale 1 inch Argillo-arenaceous underclay, *Stigmaria*.	0	1

This bed was not exposed.

	(Underclay and shale)	5	0
Coal-group 25...	Grey shale. *Coal* and coaly shale 8 inches Argillo-arenaceous underclay, *Stigmaria*.	0	8

The roof has *Alethopteris lonchitica*, *Cordaites*, and petioles of ferns. The coal shows bast tissue and remains of *Sigillaria* and *Calamites*.

	(Grey sandstone and shale, with erect *Sigillariæ* at four or five levels, and two Stigmarian underclays)	117	8
Coal-group 26...	Grey shale. *Coaly* shale 4 inches Argillo-arenaceous underclay, *Stigmaria*.	0	4

This bed was not exposed.

	(Shale and sandstone, with *Stigmaria*)	13	0
Coal-group 27...	Grey shale. *Coal* 3 inches Argillo-arenaceous underclay, *Stigmaria*.	0	3

This bed was not well exposed.

	(Grey sandstone and shale, with bituminous shale and limestone, and erect *Calamites*)	64	0

XI.

Coal-group 28...	Calcareo-bituminous shale. *Coal* and coaly shale 7 feet. Underclay, *Stigmaria*, 4 feet. Coaly shale 1 foot. *Coal* 6 inches Arenaceous underclay, *Stigmaria*.	12	6

This group is a series of thin coaly layers and underclays. The roof has *Naiadites carbonarius* and *N. elongatus*, also *Cythere* and scales of fishes. The coal contains bast tissue and different kinds of scalariform and epidermal tissues. In the lower bed is a coaly stump and an irregular layer of mineral charcoal, arising apparently from the decay of similar stumps.

	(Grey and carbonaceous shale and grey sandstone)...	29	0
Coal-group 29...	Underclay, *Stigmaria*. *Coal* and coaly shale 5 feet. Underclay 6 feet. Coal, coaly shale, and ironstone, 6 feet. *Coal* 4 feet Argillaceous underclay, *Stigmaria*.	21	0

This is a group of unusually thick beds, indicating long quiescence. The roof includes laminæ of coal, some of them composed of the bark of *Sigillaria catenoides*, also an erect *Sigillaria* rooted in the coal below. The coal and coaly shale exhibit remains of *Sigillaria*, *Cordaites*, *Lepidophyllum*, and *Cyperites*; and one layer has many hard pyritized fragments of wood. The mineral charcoal has vascular bundles of ferns, coarse scalariform tissue, and porous tissue. The underclay rests on a bed with *Naiadites*.

		ft.	in.
	(Underclay, *Stigmaria*, and grey and carbonaceous shales)	18	0
Coal-group 29*a*	Shale and coaly layers. *Coal* 4 feet Argillaceous underclay, *Stigmaria*.	4	0

The roof has obscure fragments of plants and stumps in the state of mineral charcoal. The coal shows impressions of flattened trunks, probably *Sigillariæ*. This coal contains a great variety of tissues, especially bast and scalariform of different kinds, and epidermal. My measurements in this part of the section differ somewhat from those of Sir W. E. Logan, who, I suppose, had not a good opportunity of examining the two last coals. The coal 29*a* is now mined by an adit from the shore, called the "new mine."

	(Sandstone and shale. One sandstone has many large erect *Sigillariæ*, some of them with rough and furrowed bark)	35	0
Coal-group 30	Argillaceous shale and ironstone. *Coal* 4 inches. Underclay, dark-coloured, 2 feet. Coal and coaly shale 2 inches. *Coal* 3 inches. Coaly shale 2 inches. Coal 1 inch Soft argillaceous underclay, *Stigmaria*.	3	0

The roof has bark of *Sigillaria* preserved in ironstone. The coal is pyritous, and consists of layers of mineral charcoal alternating with bright coal; it has obscure impressions of plants and bast tissue in the mineral charcoal.

X.

	(Grey shale and sandstone. One underclay, and erect *Calamites* and *Sigillaria* at two levels)	19	0
Coal-group 31	Grey sandstone. Coal and coaly shale 1 foot. Underclay, *Stigmaria*, 1 foot. Coaly shale 6 inches. *Coal* 2 inches Argillaceous underclay, *Stigmaria*.	2	8

The roof contains *Sigillariæ*, and the coal has flattened impressions of the same. This coal is remarkable as having a roof of sandstone. Its underclay is also peculiar. It is about 9 feet in thickness, and contains *Stigmaria* and nodules of ironstone throughout. It rests on a bituminous limestone containing *Naiadites* and scales of fishes, and also large roots of *Stigmaria* evidently *in situ*. This bed gives more colour to the idea of *Stigmaria* having grown under water than any other bed at the Joggins. I believe, however, that it merely implies the drying-up of a pond or creek into a swamp, subsequently inundated at intervals with muddy water.

		ft.	in.
	(Underclay and bituminous limestone, succeeded by sandstone and shale)	27	8
Coal-group 32...	Grey shale.		
	Coal and coaly shale 2 feet 4 inches	2	4
	Argillo-arenaceous underclay, *Stigmaria*.		

This is a series of thin coaly bands alternating with shales. The roof contains trunks of *Sigillaria*, *Cordaites*, *Alethopteris*, and *Cyperites*. The coal has numerous flattened trunks of *Sigillaria*.

	(Grey and reddish sandstone and shale. Five underclays, one with a film of coal and erect *Sigillariæ* at two levels)	149	0
Coal-group 33...	Coaly shale.		
	Coal 1 inch........	0	1
	Argillaceous underclay, *Stigmaria*.		

The roof has flattened trunks and vegetable fragments. The coal is a mere soil, with remains of *Sigillaria* and *Cordaites*, and vascular bundles of ferns.

	(Red and grey sandstone and shale)........	45	0
Coal-group 33*a*.	Grey shale.		
	Coal and coaly and grey shale (underclay).		
	Argillaceous underclay, *Stigmaria*.		

These layers, though not of sufficient importance to be measured as coal-bands, are most interesting as furnishing examples of what may be termed rudimentary coal-beds. Each layer is plainly composed of prostrate trunks of *Sigillaria* resting on Stigmarian underclay, and mixed with *Cordaites*, *Alethopteris lonchitica*, and vascular bundles of ferns. In one layer is a stump in the state of mineral charcoal. In another there are coprolites, scales of fishes, *Spirorbis*, and fragments of Crustaceans. In a reddish shale above these beds there is a patch of grey sandstone interlaced with Stigmarian roots, as if the sand had been prevented from drifting away by a tree or stump.

	(Reddish and grey sandstones and shales, with three or more underclays, having their coaly layers holding *Sigillaria*. Erect *Sigillariæ* at two levels)	246	0
Coal-group 34...	Underclay, with ironstone and *Stigmaria*.		
	Coal and coaly shale 2 inches.		
	Underclay, with ironstone and *Stigmaria*, 4 feet.		
	Coal and coaly shale 2 inches	4	4
	Argillo-arenaceous underclay, *Stigmaria*.		

Only obscure vegetable fragments were observed.

	(Grey and reddish sandstone and shale, with *Stigmaria*)........	13	10

		ft.	in.
Coal-group 35...	Underclay with *Stigmaria*. Coaly shale 3 inches Red and greenish underclay, a few rootlets.	0	3

The coaly shale contains many leaves of *Cordaites borassifolia*.

		ft.	in.
	(Red, grey, and dark shale, sandstone, and bituminous limestone. Three underclays and erect trees at one level)	67	9

IX.

		ft.	in.
Coal-group 36...	Bituminous limestone. Coaly shale and *coal* 3 inches. Reddish shale and ironstone, 2 feet 6 inches. *Coal* 3 inches Argillaceous underclay, *Stigmaria*.	3	0

The roof has *Stigmaria* in situ, and has been a soil or underclay. It also contains *Cythere*, fish-scales, coprolites, and *Spirorbis*. In the upper coaly shale are prostrate carbonized trunks.

		ft.	in.
	(Reddish and grey shale, sandstone, and bituminous limestone)	21	6
Coal-group 37...	Bituminous limestone and shale. *Coal* 4 inches. Underclay 1 foot 6 inches. *Coal* 6 inches. Underclay 1 foot. Bituminous limestone 3 inches. Shale 3 inches. Coal 1 inch Underclay with *Stigmaria*.	3	11

The roof has *Stigmaria*, also fish-scales, *Naiadites*, and *Cythere*. The shales are pyritized. The coal shows only obscure fragments of plants; but *Sigillariæ* in the state of ironstone occur in some of the clays.

VIII.

		ft.	in.
	(Red and grey sandstone and shale. Two underclays. Many shells of *Pupa vetusta* occur in one of these, about 12 feet below the last coal)	83	0

VII.

		ft.	in.
Coal-group 38...	Calcareo-bituminous shale. *Coal* 1 inch. Bituminous limestone 6 inches. *Coal* 2 inches. Underclay passing into chocolate shale, *Stigmaria*.		

The bituminous limestone and shale contain *Cythere*, *Naiadites elongatus* and *N. carbonarius*, coprolites, *Spirorbis*, and *Stigmaria*. The lower coal has *Sigillaria elegans*, *S. scutellata* (?), *S. Brownii*, *Alethopteris lonchitica*, *Cordaites borassifolia*, and vascular bundles of ferns.

		ft.	in.
	(Red and grey shales and sandstones, and one grey limestone with *Cythere*. One underclay. Many drift trunks, among which are *Sigillaria* and *Lepidophloios*)	123	6

V.

		ft.	in.
Coal-group 39...	Red and grey shale, with ironstone.		
	Coal ½ inch	0	0½
	Grey underclay, with *Stigmaria*, resting on bituminous limestone, with *Stigmaria* and *Cythere*.		

This thin coal consists of a layer of flattened trunks, probably of *Sigillaria*, with a quantity of mineral charcoal.

IV.

		ft.	in.
	(Red and grey shales. One bed with erect *Calamites*, another with erect *Sigillaria*)	65	4

III.

		ft.	in.
Coal-group 40...	Grey shale and ironstone.		
	Bituminous limestone and shale, with coaly films, 7 inches.		
	Underclay 1 foot.		
	Coal 1 inch.		
	Coaly shale 3 inches.		
	Underclay 1 foot.		
	Bituminous limestone 6 inches.		
	Coal and coaly shale 2 inches	3	7
	Argillaceous underclay, ironstone, and *Stigmaria*.		

The bituminous limestone and shale have *Naiadites*, *Cythere*, *Spirorbis*, scales of fishes, and coprolites, and a large spine of *Gyracanthus*, also roots of *Stigmaria*. The upper underclay holds carbonized erect trunks. The lower coal has vascular bundles of ferns and *Cordaites*. The roof supports erect stumps.

		ft.	in.
	(Underclay with ironstone nodules)	5	0
Coal-group 41...	Underclay as above.		
	Calcareo-bituminous shale and films of *coal*	3	4
	Argillaceous underclay, *Stigmaria*.		

The bituminous limestone has *Naiadites carbonarius*, *Cythere*, coprolites, and *Spirorbis*. The roof has prostrate *Sigillariæ* converted into coaly layers. The underclay has distinct stumps of *Stigmaria*.

		ft.	in.
	(Shales with *Stigmaria* and ironstone, sandstones, bituminous limestone, and carbonaceous shale at bottom)	14	4
Coal-group 42...	Bituminous limestone.		
	Coal 3 inches.		
	Shale 1 foot.		
	Coal 1 foot.		
	Underclay, *Stigmaria*, 1 foot.		
	Coal 2 inches	3	5
	Dark argillaceous underclay, *Stigmaria*.		

The roof contains *Naiadites*, *Cythere*, and coprolites. The coal is coarse, pyritous, and shaly, and has bark of *Sigillaria*, *Calamites*, and vascular bundles of ferns. It seems to be the edge of a bed, as it thins rapidly in the direction of the bank, or to the east.

II.

		ft.	in.
	(Reddish shale and sandstone with one underclay	35	0
Coal-group 43...	Reddish underclay with *Stigmaria*. Coaly shale 1 inch .... Reddish underclay, *Stigmaria*.	0	1

This bed diminishes to a mere film towards the bank.

I.

	(Reddish, grey, and dark shales and sandstone, *Stigmaria* in some beds, and erect *Sigillariæ* and *Calamites* at one level)	63	
Coal-group 44...	Grey shale with ironstone. Bituminous limestone and shale with ironstone, 10 ft. 1 in. *Coal* ½ inch. Bituminous limestone, *Stigmaria*, ½ inch. *Coal* 5 inches. Bituminous limestone, *Stigmaria*, 2 inches. *Coal* 1 inch. Bituminous limestone, *Stigmaria*, 2 inches. Coal ½ inch .... Argillo-arenaceous underclay, traces of rootlets.	11	0½

The bituminous limestone has scales of fishes, *Spirorbis*, and *Cythere*. The coal has *Cordaites* and vascular bundles of ferns.

	(Red and grey sandstone and shale. One underclay, and erect *Calamites* at one level)	98	6
Coal-group 45...	Reddish shale. Carbonaceous shale, 10 inches. Coaly matter ½ inch. Hard underclay, *Stigmaria*, 2 feet. Coaly matter ½ inch. Underclay, *Stigmaria*, 7 feet. Coal 3 inches .... Arenaceous underclay, *Stigmaria*.	10	2

In the roof of the lower coal is an erect tree. The coal has vascular bundles of ferns, remains of fern-leaves, and bast tissue. The underclay has many coaly films, apparently flattened bark of trees.

	Reddish and grey sandstone and shale	5	6
Total thickness of Division 4, according to Logan's measurements......		2539	1

e. *Division* 5.—This consists of reddish shales and red and grey sandstones. It contains no coal, and is poor in fossils, only a few drifted trunks appearing in the section. It corresponds to the upper part of the Millstone-grit series. Its thickness, according to the measurements of Sir William E. Logan, is 2082 feet.

f. *Division* 6.—This may be regarded as the middle of the Millstone-grit series. It constitutes a sort of false coal-formation, separated from the Middle Coal-formation by the barren beds of Division 5. It contains nine small or rudimentary coal-beds, which, however, are not well seen in the section, and have afforded few facts of interest. It has many thick and coarse sandstones and much red shale, with comparatively few dark-coloured beds. Its total thickness is stated by Sir W. E. Logan at 3240 feet.

Though this group contains little coal, it is to be observed that it has many underclays, indicating soils which supported forests of *Sigillaria*, and that erect *Sigillariæ* occur very near the base of the division. The absence of important beds of coal is therefore due to the local physical conditions, and not to the want of the necessary vegetation.

		ft.	in.
	(Sandstones and shales with many drifted trunks of *Dadoxylon*)	539	7
Coal-group 1 ...	Blackish grey shale. Calcareous shale 1 foot. Black shale 3 feet. *Coaly shale* 2 inches Argillo-arenaceous underclay, *Stigmaria*.	4	2
	(Red and grey sandstone and shale and concretionary limestone, trunks of *Dadoxylon* and other trees. One underclay)	160	1
Coal-group 2 ...	Grey shale. *Coaly shale* 1 inch Reddish and grey underclay, *Stigmaria*.	0	1
	(Series of underclays with *Stigmaria*. The beds are reddish or grey, and arenaceous)	19	1
Coal-group 3 ...	Reddish shale. *Coaly shale* 1 inch. Greenish shale 6 inches. *Coaly shale* 1 inch. Greenish shale 2 feet 6 inches. *Coaly shale* 3 inches. Greenish shale 1 inch. *Coal* and coaly shale 3 inches Argillo-arenaceous underclay, *Stigmaria*.	3	9

The coal contains bast tissue and reticulated, porous, and scalariform tissues of *Sigillaria* and *Calamodendron*.

		ft.	in.
	(Series of underclays as before)	12	0
Coal-group 4 ...	Underclay, *Stigmaria*. *Coal* and coaly shale 3 inches Argillo-arenaceous underclay, *Stigmaria*.	0	3
	(Series of underclays as before)	24	0
Coal-group 5 ...	Grey shale. *Coaly matter* ½ inch Greenish underclay, *Stigmaria*.	0	½
	(Underclay and sandstone, the latter with an erect *Sigillaria*)	10	0
Coal-group 6 ...	Sandstone (erect *Sigillaria* as above), *Coaly shale* 3 inches Argillo-arenaceous underclay, *Stigmaria*.	0	3
	(Fifteen feet of underclay, under which a thick sandstone with great quantities of drifted trunks of *Dadoxylon* and *Sigillaria*. Below this alternations of grey and red sandstone and shale)	210	10
Coal-group 7 ...	Grey sandstone. Bituminous limestone 3 inches. Grey shale 3 feet. Grey limestone 2 inches. *Coaly shale* 6 inches. Bituminous limestone 3 inches. *Coaly shale* 1 foot. *Coal* 1 inch Argillo-arenaceous underclay, *Stigmaria*.	5	3

The lower bituminous limestone contains *Naiadites ovalis*, *Cythere*, and scales of Lepidoid fishes. The lower coal has much *Cyperites* and bark of *Sigillaria*, also bast tissue in mineral charcoal.

		ft.	in.
	(Thick beds of grey sandstone and grey shale, with drifted trunks of *Dadoxydon*, *Sigillaria*, and *Calamites*, and leaves of *Cordaites*)	532	0
Coal-group 8 ...	Grey shale.		
	Coal ½ inch	0	½
	Argillo-arenaceous underclay, *Stigmaria*.		

This coal is laminated, the laminæ being bark of *Sigillariæ*. The underclay is very rich in *Stigmaria*.

	(Grey sandstone with grey and red shale. Many drifted trunks of *Sigillaria* and *Calamites*, and an erect *Sigillaria* in the lowest bed of sandstone)	1224	0
Coal-group 9 ...	Grey shale.		
	Coaly matter and carbonaceous shale	0	2
	Argillo-arenaceous underclay, *Stigmaria*, and ironstone.		
	(Grey and red sandstone and shale and calcareous bands, some of them bituminous. Near the middle a thick band of laminated black shale with *Naiadites lævis*, *Cyperites*, and *Lepidostrobus*. Drifted *Calamites* in the sandstones)	496	4
Total thickness, according to Logan		3240	9

g. *Division* 7.—This division consists principally of red and chocolate shales with red and grey sandstone, arenaceous conglomerates, and thin beds of concretionary limestone. It may be regarded as the base of the Millstone-grit formation. Its thickness is stated by Sir W. E. Logan at 650 feet.

No fossils, other than carbonized fragments of plants, have been found in this division.

h. *Division* 8.—This division consists of reddish shales with greenish and red sandstone, grey shale, grey compact limestone, and gypsum. It may be regarded as the upper part of the Lower Carboniferous formation; and almost immediately under its lowest beds there are marine limestones with *Productus cora* and other characteristic Lower Carboniferous fossils.

Only fragments of plants, often replaced by sulphuret of copper, have been found in this division. Its thickness is stated by Logan at 1658 feet.

§ IV. Remarks on the Animals and Plants whose Remains occur in the Coal.

1. *Introduction.*—Under this heading I shall, in the first place, present a tabular view of the relative frequency of occurrence of the several genera in the beds of coal and their roof-shales, without reckoning the almost invariable occurrence of *Stigmaria* in the underclays, which is of course to be taken as an indication of the existence of Sigillarioid trees in connexion with the growth of the coal.

The number of coals reckoned may vary according to the manner in which the several layers are grouped; but as arranged in the above sectional list it amounts to eighty-one in all. Of these, 23 are found in Division 3 of Logan's section, being the upper member of the Middle Coal-formation; 49 are found in Division 4 of Logan's section, being the lower member of the Middle Coal-formation; 9 occur in Division 6 of Logan's section, or in the equivalent of the Millstone-grit. In the latter group few of the coals were sufficiently well exposed to enable a satisfactory examination to be made. I have grouped the remains under three heads—External Forms of Plants, Microscopic Structure of Plants, and Animal Remains—and have arranged the forms under each in the order of their relative frequency of occurrence.

Table showing the Relative Frequency of Occurrence of Genera of Plants and Animals in the Coals of the South Joggins.

Names of Fossils.		Division 3. 23 coals.	Division 4. 49 coals.	Division 6. 9 coals.	Total. 81 coals.
Plants.					
Sigillaria...............	occurs in	13	34	2	49
Cordaites	,,	15	26	...	41
Filices (mostly *Alethopteris lonchitica*)	,,	4	17	2	23
Lepidodendron and Lepidophloios ...	,,	1	15	...	16
Calamites	,,	4	12	...	16
Carpolites, &c.	,,	2	9	...	11
Asterophyllites	,,	1	2	...	3
Calamodendron	,,	...	1	...	1
Structures.					
Vascular bundles of ferns	,,	8	22	...	30
Bast tissue (*Sigillaria*)	,,	2	16	2	20
Epidermal tissue (*Cordaites*, &c.) ...	,,	6	6	...	12
Scalariform (*Sigil.*, *Stig.*, *Lepidod.*, &c.)	,,	1	9	1	11
Discigerous (*Sigillaria* and *Dadoxylon*, &c.)	,,	1	8	1	10
Reticulated (*Calamodendron*, Ferns, &c.)	,,	...	2	1	3
Animals.					
Fishes (*Palæoniscus*, *Rhizodus*, &c.) ...	,,	1	16	1	18
Naiadites (*Anthracomya*, &c.).........	,,	...	16	1	17
Spirorbis carbonarius	,,	...	16	...	16
Cythere	,,	...	13	1	14
Insects (?)	,,	...	3	...	3
Reptiles (*Dendrerpeton*, &c.)	,,	...	1	...	1
Pupa vetusta and *Xylobius sigillariæ*......	,,	...	1	...	1

It will be observed that, whether we regard the external forms or the internal structures preserved, the predominant plants are *Sigillaria, Cordaites,* and Ferns, with *Lepidodendron* and *Calamites.* The substance of the coal itself. so far as its structure is preserved, may be said to be principally composed of bark of *Sigillaria* and leaves and stems of ferns and *Cordaites.* In regard to the proportions in different parts of the series, little difference exists, except that *Cordaites* and *Calamites* are rather more abundant in the upper coals, and *Lepidodendron* in the lower, while the middle of the series is the headquarters of *Sigillaria* and ferns. Remains of aquatic animals occur in connexion with a large proportion of the coals, more especially in the middle of the series. This may be explained in connexion with the theory of growth of the coal *in situ* by the following considerations:—(1) It was necessary to the preservation of the vegetable matter composing a bed of coal that it should be submerged and covered with sediment. (2) On the submergence of a swamp covered with standing trees and other vegetation, these would prevent the passage of strong currents carrying coarse detritus, and the area would be covered with fine sediment deposited in still water and under conditions favourable to certain kinds of aquatic animals. (3) When the currents carrying detritus were sufficiently powerful to uproot and sweep away the forests and the brakes of *Calamites,* they would also remove or disturb the vegetable soil. It follows that we should expect the more important coals to be covered with fine sediment containing animal as well as vegetable remains, and that beds roofed with sandstone or coarse shale must either have been of small area or sparsely covered with trees at the time of their submergence. This accounts for the otherwise anomalous circumstance that the evidences of aqueous conditions in association with the coal are proportionally more abundant in the middle than in the upper part of the Coal-measures. We may now proceed to consider the genera of plants and animals separately, in their relation to the growth of coal.

2. *Coniferous Trees.*—Four species of coniferous trees, referable to the genus *Dadoxylon,* have been found in the Coal-formation of Nova Scotia. They are known to me only by the microscopic structure of their wood; but on the evidence afforded by this I have named and described them as new species*. One of them, *D. antiquius,* is closely allied to *D. Withami* of Great Britain, and, like that species, belongs to the Lower Carboniferous Coal-measures. Its structure is of that character for which Brongniart proposed the generic name "*Palæoxylon.*" It has not yet been found at the Joggins. Another species, *D. Acadianum,* is found abundantly at the Joggins in the condition of drifted trunks imbedded in the sandstone of the lower part of the Coal-formation and the upper part of the Millstone-grit series. The third species, *D. materiarium,* is very near to *D. Brandlingii* of Great Britain, and may possibly be only a variety. It is especially abundant in the sandstone of the Upper Coal-formation, in

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* Descriptions referred to here and in subsequent pages will be found in "Synopsis of the Flora of the Carboniferous Period," Can. Nat. vol. viii., and in the Appendix.

which vast numbers of drifted trunks of this species occur in some places. The fourth species, *D. annulatum*, presents a very peculiar structure, probably of generic value. It has alternate concentric rings of discigerous woody tissue, of the character of that of *Dadoxylon*, and of compact structureless coal, which either represents layers of very dense wood or, more likely, of corky cellular tissue. In the latter case the structure would have affinities with that of certain *Gnetaceæ* and of Cycads.

Though coniferous trees usually occur as decorticated and prostrate trunks, I have recorded the occurrence of one erect specimen, in a sandstone a little above the "Main Coal," at the Joggins. It probably belonged to the species last named. Tissues of coniferous trees are very rare in the coal itself. Most of the discigerous tissues found in the coal belong to *Sigillaria* and *Calamodendron*. From the abundance of coniferous trees in sandstones above and below the coal, and their comparative absence in the coal and coal-shales, it may be inferred that these trees belonged rather to the uplands than to the coal-swamps; and the great durability and small specific gravity of coniferous wood would allow it to be drifted, either by rivers or ocean-currents, to very great distances. I am not aware that the fruits of pine trees occur at the Joggins, unless some of the *Trigonocarpa* are of this character. Nor has any foliage of these trees been found; but at Tatmagonche, in the continuation of the Upper Coal-formation, there are leafy branchlets which I have named *Araucarites gracilis*, and which may possibly have belonged to *Dadoxylon materiarium*.

The casts of pith-cylinders known as *Sternbergiæ* are abundant in some of the sandstones, especially in the Upper Coal-formation. I have shown that in Nova Scotia, as in England, some of these singular casts belong to *Dadoxylon**; but as the pith-cylinder of *Sigillaria* and of *Lepidophloios* was of a similar character, those which are destitute of woody investment cannot be determined with certainty, though in general the transverse markings are more distant in the *Sternbergiæ* of *Sigillaria* and *Lepidophloios* than in those of *Dadoxylon*.

In Plate V., and in Plate VI. fig. 14, I have given illustrations of the coniferous plants above referred to.

3. *Sigillariæ*.—I have catalogued or described no less than twenty-one species belonging to this family, from the Coal-measures of Nova Scotia. They may be arranged under the following provisional genera:—

(1.) FAVULARIA, *Sternberg*	Sigillaria elegans, *Brongn.*
	—— tessellata, *Brongn.*
	—— Bretonensis, *Dawson.*
(2.) RHYTIDOLEPIS, *Sternberg* ..	—— scutellata, *Brongn.*
	—— Schlotheimiana, *Brongn.*
	—— Saullii, *Brongn.*
	—— Dournaisii, *Brongn.*
	—— Knorrii, *Brongn.*

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* Proceedings of the American Association, 1837, Canadian Naturalist, vol. ii. Paper on Structures of Coal, Quart. Journ. Geol. Soc. 1860.

(2.) Rhytidolepis (*continued*)	Sigillaria pachyderma, *Brongn.*
	—— flexuosa, *L. & H.*?
	—— elongata, *Brongn.*
(3.) Sigillaria, *Brongn.*	—— reniformis, *Brongn.*
	—— Brownii, *Dawson.*
	—— lævigata, *Brongn.*
	—— planicosta, *Dawson.*
	—— catenoides, *Dawson.*
	—— striata, *Dawson.*
	—— eminens, *Dawson.*
(4.) Clathraria, *Brongn.*	—— Menardi, *Brongn.*
(5.) Leioderma, *Goldenb.* .... (Asolanus, *Wood*).	—— Sydnensis, *Dawson.*
(6.) Syringodendron, *Sternb.*..	—— organum, *L. & H.*

Of these, seven are probably new species, and the remainder can be identified with reasonable certainty with European species. The differences in the markings in different parts of the same tree are, however, so great, that I regard the greater part of the recognized species of *Sigillariæ* as merely provisional. Even the generic limits may be overpassed when species are determined from hand specimens. A fragment of the base of an old trunk of *Sigillaria* proper would necessarily be placed in the genus *Leioderma*, and a young branch of *Favularia* has all the characters of the genus *Clathraria*. It is, however, absolutely necessary to make some attempt at generic distinction among the diverse forms included in the genus *Sigillaria*; otherwise it will be impossible to reconcile the conflicting statements of authors as to the dimensions, habit of growth, foliage, roots, and fructification of these singular plants;—such statements usually applying to one or more of the subordinate generic types. I shall therefore notice separately, and with especial reference to their function in the production of coal, the several generic or subgeneric forms, beginning with that which I regard as the most important—namely, *Sigillaria* proper, of which, in Nova Scotia, I regard the species which I have named *S. Brownii* (figs. 15 to 20, Pl. VI.) as the type. Other species are represented in figs. 21 to 28.

In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens[*]; the pith is transversely partitioned in the manner of *Sternbergia*; and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in in the coal, named "bast tissue." The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree. The roots were *Stigmariæ* of the type of the ordinary *S. ficoides*. I have not seen the leaves or fruits attached; but, from the associations observed, I believe that the former were long, narrow, rigid, and two- or three-nerved (*Cyperites*), and that the latter were *Trigonocarpa*, borne in racemes on the upper part of the stem. These trees attained to a great size. I have seen one trunk four feet in diameter, and specimens of two feet or more in diameter are common: some of these trunks have been traced for thirty or forty feet without branching. The greater number of the erect stumps preserved at the Joggins appear to belong to this genus, which also seems to have contributed very largely to the formation of coal. Judging from the paucity of their foliage, the density of their tissues, and the strong structural resemblance of their stems and roots to those of Cycads, I believe that their rate of growth must have been very slow.

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[*] Quart. Journ. Geol. Soc., paper on Structures of Coal.

The genus *Rhytidolepis*, in which the areoles are large, hexagonal, and tripunctate, and the ribs narrow and often transversely striate, ranks as a coal-producer next to *Sigillaria* proper, and is equally abundant in the Coal-measures. These trees seem to have been of smaller size and feebler structure than the last mentioned, and are less frequently found in the erect position; but they are very abundant on the roofs of the coal-beds. Judging from such specimens as I have seen, their roots were less distinctly Stigmarioid than in the last genus, though this appearance may arise from difference of preservation. Their leaves were of the same type as in the last genus; and their stems bear rings of irregular scars, which may mark stages of growth, or the production of slender racemes of fruit in a verticillate manner. The woody axis of the stems of this genus was composed of scalariform and coarsely porous tissues, much like those of modern Cycads. I figure, as an illustration of the genus, a fragment of *S. scutellata* showing one of the belts of abnormal scars.

The genus *Favularia* is represented in Nova Scotia principally by the typical species *S. elegans* of Brongniart. The admirable investigations of the structure of the stem of this species by Brongniart, with the further illustrations given by Corda, Hooker, and Goldenberg, still afford the best general views of the structure of *Sigillariæ* which we possess*. It is to be observed, however, that Brongniart's specimen was a young stem or a branch, and that it affords a very imperfect idea of the development of discigerous and bast tissues in the full-grown stems of *Sigillaria* proper. The trees of this genus appear to have been of small growth; and they branched in the manner of *Lepidodendron*, the smaller branches being quite destitute of ribs, and with the areoles elliptical and spirally disposed. The stems show joints or rings of peculiar scars at intervals, as in the last genus. The leaves differ from those of the other genera, being broad and with numerous slender parallel veins, almost in the manner of *Cordaites*. (Figs. 26 and 27, Plate VII.)

The genus *Clathraria* is evidently closely allied to the above, and is possibly founded on branches of trees of the genus *Favularia*. It is a rare form in Nova Scotia.

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* See also Binney "On some Fossil Plants showing Structure, from the Lower Coal-measures of Lancashire," Quart. Journ. Geol. Soc. vol. xviii. p. 106.—Edit.

Of the genus *Leioderma* or *Asolanus* I know but one species, independently of those specimens of old trunks of the ordinary *Sigillaria* in which the ribs have disappeared. My species, *S. Sydnensis*, is founded on specimens collected by Mr. Brown at Sydney, Cape Breton, which are especially remarkable for the curious modification which they present of the Stigmarian root. The specimens described by Mr. Brown under the name of *S. alternans**, and which have been copied by Geinitz and Goldenberg, belong, I believe, to this species. (Fig. 28, Plate VII.)

On the genus *Syringodendron* of Sternberg I have no observations to make. I have seen only fragments of stems; and these seem to be very rare.

I include under *Sigillariæ* the remarkable fossils known as *Stigmaria*, being fully convinced that all the varieties of these plants known to me are merely roots of *Sigillaria*; I have verified this fact in a great many instances, in addition to those so well described by Mr. Binney and Mr. Brown. The different varieties or species of *Stigmaria* are no doubt characteristic of different species of *Sigillaria*, though in very few cases has it proved possible to ascertain the varieties proper to the particular species of stem. The old view, that the *Stigmariæ* were independent aquatic plants, still apparently maintained by Goldenberg and some other palæobotanists, evidently proceeds from imperfect information. Independently of their ascertained connexion with *Sigillaria*, the organs attached to the branches are not leaves, but rootlets. This was made evident long ago by the microscopic sections published by Goeppert, and I have ascertained that the structure is quite similar to that of the thick fleshy rootlets of *Cycas*. The lumps or tubercles on these roots have been mistaken for fructification; and the rounded tops of stumps, truncated by the falling in of the bark or the compression of the empty shell left by the decay of the wood, have been mistaken for the natural termination of the stem†. The only question remaining in regard to these organs is that of their precise morphological place. Their large pith and regular areoles render them unlike true roots; and hence Lesquereux has proposed to regard them as *rhizomes*. But they certainly radiate from a central stem, and are not known to produce any true buds or secondary stems. In short, while their function is that of roots, they may be regarded, in a morphological point of view, as a peculiar sort of underground branches. They all ramify very regularly in a dichotomous manner, and, as Mr. Brown has shown, in some species at least, give off conical tap-roots from their underside.

In all the *Stigmariæ* exhibiting structure which I have examined, the axis exhibits only scalariform vessels. Corda, however, figures a species with wood-cells, or vessels with numerous pores, quite like those found in the stems of *Sigillaria* proper; and, as Hooker has pointed out, the arrangement of the tissues in *Stigmaria* is similar to that in

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* Quart. Journ. Geol. Soc. vol. v. p. 354 *et seq.*

† For examples of the manner in which a natural termination may be simulated by the collapse of bark or by constriction owing to lateral pressure, see my papers, Quart. Journ. Geol. Soc. vol. x. p. 35, and vol. vii. p. 194.

Sigillaria. After making due allowance for differences of preservation, I have been able to recognize eleven species or forms of *Stigmaria* in Nova Scotia, corresponding, as I believe, to as many species of *Sigillaria**. At the Joggins, *Stigmariæ* are more abundant than any other fossil plants. This arises from their preservation in the numerous fossil soils or *Stigmaria* underclays. Their bark, and mineral charcoal derived from their axes, also abound throughout the thickness of the coal-beds, indicating the continued growth of *Sigillaria* in the accumulation of the coal. (Figs. 83 to 87 Pl. XII.)

Our knowledge of the fructification of *Sigillaria* is as yet of a very uncertain character. I am aware that Goldenberg has assigned to these plants leafy strobiles containing spore-capsules: but I do not think the evidence which he adduces conclusive as to their connexion with *Sigillaria*; and the organs themselves are so precisely similar to the strobiles of *Lepidophloios*, that I suspect they must belong to that or some allied genus. The leaves, also, with which they are associated in one of Goldenberg's figures seem more like those of *Lepidophloios* than those of *Sigillaria*. If, however, these are really the organs of fructification of any species of *Sigillaria*, I think it will be found that we have included in this genus, as in the old genus *Calamites*, two distinct groups of plants, one cryptogamous, and the other phænogamous, or else that male strobiles bearing pollen have been mistaken for spore-bearing organs.

I cannot pretend that I have found the fruit of *Sigillaria* attached to the parent stem; but I think that a reasonable probability can be established that some at least of the fruits included, somewhat vaguely, by authors under the names of *Trigonocarpum* and *Rhabdocarpus* were really fruits of *Sigillaria*. These fruits are excessively abundant and of many species, and they occur not only in the sandstones but in the fine shales and coals and in the interior of erect trees, showing that they were produced in the coal-swamps. The structures of these fruits show that they are phænogamous and probably gymnospermous. Now the only plants known to us in the coal-formation, whose structures entitle them to this rank, are the *Conifers*, *Sigillariæ*, and *Calamodendra*. All the others were in structure allied to cryptogams, and the fructification of most of them is known. But the Conifers were too infrequent in the Carboniferous swamps to have afforded numerous species of *Carpolites*; and, as I shall presently show, the *Calamodendra* were very closely allied to *Sigillariæ*, if not members of that family. Unless, therefore, these fruits belonged to *Sigillaria*, they must have been produced by some other trees of the coal-swamps, which, though very abundant and of numerous species, are as yet quite unknown to us. Some of the *Trigonocarpa* have been claimed for Conifers, and their resemblance to the fruits of *Salisburya* gives countenance to this claim; but the Conifers of the Coal-period are much too few to afford more than a fraction of the species. One species of *Rhabdocarpus* has been attributed by Geinitz to the genus *Nœggerathia*; but the leaves which he assigns to it are very like those of *Sigillaria elegans*, and may belong to some allied species. With regard to the mode of attachment of these fruits, I have shown that one species, *Trigonocarpum racemosum* of the Devonian strata*, was borne on a rhachis in the manner of a loose spike, and I am convinced that some of the groups of inflorescence named *Antholithes* are simply young *Rhabdocarpi* or *Trigonocarpa* borne in a pinnate manner on a broad rhachis and subtended by a few scales. Such spikes may be regarded as corresponding to a leaf with fruits borne on the edges, in the manner of the female flower of *Cycas*; and I believe with Goldenberg that these were borne in verticils at intervals on the stem. In this case it is possible that the strobiles described by that author may be male organs of fructification containing, not spores, but pollen. In conclusion, I would observe that I would not doubt the possibility that some of the fruits known as *Cardiocarpa* may have belonged to Sigillarioid trees. I am aware that some so-called *Cardiocarpa* are spore-cases of *Lepidodendron*; but there are others which are manifestly winged nutlets allied to *Trigonocarpum*, and which must have belonged to phænogams. It would perhaps be unwise to insist very strongly on deductions from what may be called circumstantial evidence, as to the nature of the fruit of *Sigillaria*; but the indications pointing to the conclusions above stated are so numerous that I have much confidence that they will be vindicated by complete specimens, should these be obtained. (Figs. 29 and 30, Pl. VII., and figs. 69 to 79, Pl. XII.)

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* See Appendix.

All of the Joggins coals, except a few shaly beds, afford unequivocal evidence of *Stigmaria* in their underclays; and it was obviously the normal mode of growth of a coal-bed, that, a more or less damp soil being provided, a forest of *Sigillaria* should overspread this, and that the Stigmarian roots, the trunks of fallen *Sigillariæ*, their leaves and fruits, and the smaller plants which grew in their shade, should accumulate in a bed of vegetable matter to be subsequently converted into coal—the bark of *Sigillaria* and allied plants affording "bright coal," the wood and bast tissues mineral charcoal, and the herbaceous matter and mould dull coal. The evidence of this afforded by microscopic structure I have endeavoured to illustrate in a former paper†.

The process did not commence, as some have supposed, by the growth of *Stigmaria* in ponds or lakes. It was indeed precisely the reverse of this, the *Sigillaria* growing in a soil more or less swamp but not submerged, and the formation of coal being at last arrested by submergence. I infer this from the circumstance that remains of Cyprids, Fishes, and other aquatic animals are rarely found in the underclays and lower parts of the coal-beds, but very frequently in the roofs, while it is not unusual to find mineral charcoal more abundant in the lower layers of the coal. For the formation of a bed of coal, the sinking and subsequent burial of an area previously dry seems to have been required. There are a few cases at the Joggins where *Calamites* and even *Sigillariæ* seem to have grown on areas liable to frequent inundation; but in these cases coal did not accumulate. The non-laminated, slickensided and bleached condition of most of the underclays indicates soils of considerable permanence.

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* "Flora of the Devonian Period," Quart. Journ. Geol. Soc. vol. viii. p. 324.

† "On the Structures in Coal," Quart. Journ. Geol. Soc. 1859.

In regard to beds destitute of Stigmarian underclays, the very few cases of this kind apply only to shaly coals filled with drifted leaves, or to accumulations of vegetable mud capable of conversion into impure coal. The origin of these beds is the same with that of the carbonaceous shales and bituminous limestones already referred to. It will be observed in the section that in a few cases such beds have become sufficiently dry to constitute underclays, and that conditions of this kind have sometimes alternated with those favourable to the formation of true coal.

There are some beds at the Joggins, holding erect trees *in situ*, which show that *Sigillariæ* sometimes grew singly or in scattered clumps, either alone or amidst brakes of *Calamites*. In other instances they must have grown close together, and with a dense undergrowth of ferns and *Cordaites*, forming an almost impenetrable mass of vegetation.

From the structure of *Sigillariæ* I infer that, like Cycads, they accumulated large quantities of starch, to be expended at intervals in more rapid growth, or in the production of abundant fructification. I adhere to the belief expressed in previous papers that Brongniart is correct in regarding the *Sigillariæ* as botanically allied to the *Cycadaceæ*, and I have recently more fully satisfied myself on this point by comparisons of their tissues with those of *Cycas revoluta*. It is probable, however, that when better known they will be found to have a wider range of structure and affinities than we now suppose.

There are some reasons for believing that the trees described by Corda under the names of *Diploxylon*, *Myelopithys*, and *Heterangium*, and also the *Anabathra* of Witham, are *Sigillariæ*. Much of the tissue discribed by Goeppert as *Araucarites carbonarius* is probably also Sigillarian.

4. *Calamodendron*.—The plants of this genus are quite distinct from *Calamites* proper. A *Calamodendron* as usually seen is a striated cast with frequent cross lines or joints; but when the whole stem is preserved, it is seen that this cast represents merely an internal pith-cylinder, surrounded by a woody cylinder composed in part of scalariform or reticulated vessels, and in part of wood-cells with one row of large pores on each side. External to the wood was a cellular bark, and the outer surface seems to have been simply ribbed in the manner of *Sigillaria*. It so happens that the internal cast of the pith of *Calamodendron*, which is really of the nature of a *Sternbergia*, so closely resembles the external appearance of the true Calamites as to be constantly mistaken for them. Most of these pith-cylinders of *Calamodendron* have been grouped in the species *Calamites approximatus*; but that species, as understood by some authors, appears also to include true *Calamites**, which, however, when well preserved, can always be distinguished by the scars of the leaves or branchlets which were attached to the nodes.

Calamodendron would seem, from its structure, to have been closely allied to *Sigillaria*, though, according to Unger, the tissues were differently arranged, and the woody cylinder must have been much thicker in proportion.

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* See Geinitz, "Steinkohlenformation in Sachsen."

The tissues of *Calamodendron* are by no means infrequent in the coal, and casts of the pith are common in the sandstones; but its foliage and fruit are unknown. (Fig. 31, Pl. VII., *a* to *c*.)

5. *Calamites.*—Nine species of true *Calamites* have been recognized in Nova Scotia, of which seven occur at the Joggins, the most abundant being *C. Suckovii* and *C. Cistii*. The Calamites grew in dense brakes on sandy and muddy flats. They were unquestionably allied to *Equisetaceæ*, and produced at their nodes either verticillate simple linear leaves, as in *C. Cistii*, or verticillate branchlets with pinnate or verticillate leaflets, as in *C. Suckovii* and *C. nodosus*. The Calamites do not seem to have contributed much to the growth of coal, though their remains are not infrequent in it. The soils in which they most frequently grew were apparently too wet and liable to inundation and silting up to be favourable to coal-accumulation. I have elsewhere shown that some of the species of *Calamites* gave off numerous adventitious roots from the lower parts of their stems, and also multiplied by budding at their bases*.

Of the genus *Equisetites* one species has been found in Cape Breton; but it has not as yet been recognized at the Joggins. (Fig. 88, Pl. XII.)

6. *Asterophyllites*, &c.—Five species of *Asterophyllites*, one of *Annularia*, five of *Sphenophyllum*, and three of *Pinnularia*, have been found in Nova Scotia. I place these together as probably allied plants. The *Pinnulariæ* were apparently slender roots, with thin epidermis, cellular bark, and a central axis. The others were probably low plants growing in wet places. I am not aware that they contributed to any great extent to the accumulation of coal; but as their tissues were scalariform, similar to those of ferns, it would not be easy to recognize them. A beautiful specimen of *Sphenophyllum emarginatum* from New Brunswick, in the collection of Sir W. E. Logan, has enabled me to ascertain that its stem had a simple axis of one bundle of reticulato-scalariform vessels, like those of *Tmesipteris* as figured by Brongniart. These curious plants were no doubt cryptogamous, having a habit of growth like that of *Equisetaceæ*, leaves like those of ferns or *Marsiliaceæ*, and fructification and structure like those of *Lycopodiaceæ*. They were closely allied to *Asterophyllites* and *Annularia*.

7. *Filices.*—Of the numerous species of ferns in the Carboniferous rocks of Nova Scotia, only a very few have been recognized at the Joggins. This may in part be due to the soft and crumbling character of the shales; but after much examination I am inclined to believe that the flora of the Joggins was originally poor in ferns. While the coal-field of Sydney, Cape Breton, has afforded forty-six species, the Joggins and its vicinity have as yet yielded only six or seven. Of these by far the most abundant is *Alethopteris lonchitica*, which appears throughout the Middle Coal-formation under a great number of varietal forms. It is also found abundantly at Springhill. At

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* Quart. Journ. Geol. Soc. vol. x. p. 34

Sydney, on the contrary, *Pecopteris abbreviata* and *Alethopteris nervosa* are the most common ferns. But though fronds of ferns are comparatively rare at the Joggins, except in a few beds, and these holding principally the species *Alethopteris lonchitica*, bundles of scalariform vessels referable to ferns occur very plentifully in the coarser parts of the coal-beds, and would seem to indicate that vast quantities of stipes and fronds have been resolved into coal. It is to be observed, however, that it is not in all cases possible to distinguish the vascular bundles of ferns from those of the leaves of Sigillarioid and Lycopodiaceous plants. (Fig. 67, Pl. XII.)

Trunks of two species of tree ferns of the genus *Palæopteris* have been found in Nova Scotia and New Brunswick, and also obscure fragments, probably of *Caulopteris* and *Psaronius*. (Figs. 35 & 36, Pl. VIII.)

8. *Megaphyton.*—These are perhaps the most curious and puzzling plants of the coal. Their thick stems, marked by linear scars and having two rows of large depressed areoles on the sides, suggest no affinities to any known plants. They are usually ranked with *Lepidodendron* and *Ulodendron*, but sometimes, and probably with greater reason, are regarded as allied to tree ferns. At the Joggins a very fine species (*M. magnificum*) has been found, and at Sydney a smaller species (*M. humile*); but both are rare and not well preserved. If the large scars supported cones and the smaller leaves, then, as Brongniart remarks, the plant would much resemble *Lepidophloios*, in which the cone-scars are thus sometimes distichous. But the scars are not round and marked with radiating scales as in *Lepidophloios*; they are reniform or oval, and resemble those of tree ferns, for which reason they may be regarded as more probably leaf-scars*; and in that case the smaller linear scars would indicate ramenta, or small aërial roots. Further, the plant described by Corda as *Zippea disticha* is evidently a *Megaphyton*, and the structure of that species is plainly that of a tree fern of somewhat peculiar type. On these grounds I incline to the opinion of Geinitz, that these curious trees were allied to ferns, and bore two rows of large fronds, the trunks being covered with coarse hairs or small aërial roots. At one time I was disposed to suspect that they may have crept along the ground; but a specimen from Sydney shows the leaf-stalks proceeding from the stem at an angle so acute that the stem must, I think, have been erect. From the appearance of the scars it is probable that only a pair of fronds were borne at one time at the top of the stem; and if these were broad and spreading, it would be a very graceful plant. To what extent plants of this type contributed to the accumulation of coal I have no means of ascertaining, their tissues in the state of coal not being distinguishable from those of ferns and Lycopodiaceæ.

The species *Megaphyton humile* had, like Corda's *Zippea disticha*, a thick central axis striated longitudinally, and giving off very thick bundles of fibres, and probably scalariform vessels, to the bases of the leaves. (Figs. 33 & 34, Pl. VIII.)

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* This is the view of Lindley, 'Fossil Flora,' p. 116.

9. *Lepidodendron.*—Of this genus nineteen species have been recorded as occurring in the Carboniferous rocks of Nova Scotia. Of these, six occur at the Joggins, where specimens of this genus are very much less abundant than those of *Sigillaria*. In the newer Coal-formation *Lepidodendra* are particularly rare, and *L. undulatum* is the most common species. In the Middle Coal-formation *L. rimosum*, *L. dichotomum*, *L. elegans*, and *L. Pictoense* are probably the most common species; and *L. corrugatum* is the characteristic *Lepidodendron* of the Lower Carboniferous, in which plants of this species seem to be more abundant than any other vegetable remains whatever.

To the natural history of this well-known genus I have little to add, except in relation to the changes which take place in its trunk in the process of growth, and the study of which is important in order to prevent the undue multiplication of species. These are of three kinds. In some species the areoles, at first close together, become, in the process of the expansion of the stem, separated by intervening spaces of bark in a perfectly regular manner; so that in old stems, while widely separated, they still retain their arrangement, while in young stems they are quite close to one another. This is the case in *L. corrugatum* (Pl. XI.). In other species the leaf-scars or areoles increase in size in the old stems, still retaining their forms and their contiguity to each other. This is the case in *L. undulatum*, and generally in those *Lepidodendra* which have very large areoles. In these species the continued vitality of the bark is shown by the occasional production of lateral strobiles on large branches, in the manner of the modern Red Pine of America. In other species the areoles neither increase in size nor become regularly separated by growth of the intervening bark; but in old stems the bark splits into deep furrows, between which may be seen portions of bark still retaining the areoles in their original dimensions and arrangement. This is the case with *L. Pictoense*. This cracking of the bark no doubt occurs in very old trunks of the first two types, but not at all to the same extent. I figure three examples of these peculiarities in mode of growth:—

Lepidodendron corrugatum, Dawson.—I quote in the Appendix my description of this species, and may refer to the figures in Plate XI. for further illustration. I do not know any other species in Nova Scotia which has the same habit of growth; but *L. oculatum* and *L. distans* of Lesquereux show a tendency to it. The present species is exclusively Lower Carboniferous, and occurs on that horizon in New Brunswick, in Pennsylvania, and, I believe, also in Ohio; though the beds holding it in the latter State have been by some regarded as Devonian.

L. undulatum, Sternberg.—I think it not improbable that several closely allied species are included under this name. On the other hand, all the large-areoled *Lepidodendra* figured in the books must have branches with small scars, which, in the present state of knowledge, it is impossible to identify with this species. I suppose that *L. elegans* resembles the present species in its mode of growth, at least if the large-scarred specimens attributed to it are really of the same species. *L. dichotomum* (=*L. Sternbergii*) also resembles it to some extent. (Fig. 41, Pl. IX.)

L. Pictoense, Dawson.—This species I described as follows, from young stems, in my "Synopsis of the Coal-Plants of Nova Scotia:"—"Areoles contiguous, prominent, separated in young stems by a narrow line, long-oval, acuminate; breadth to length as 1 to 3 or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch."

Additional specimens from Sydney show that in old trunks of this species the areoles do not enlarge, but the bark becomes split into strips. I have reason to think that a new species from Nova Scotia which I have described in the Appendix, *L. personatum*, agrees with it in this respect. (Figs. 37, 38, and 39, Pl. IX.)

The *Lepidodendra* resemble each other too closely to admit of good subgeneric distinction. The grounds on which the distinction of *Sagenaria* and *Aspidiaria* is founded are quite worthless, the apparent position of the vascular scars in the areoles depending on accidents of preservation much more than on original differences. The genus *Knorria* includes many peculiar conditions of decorticated *Lepidodendra*.

In regard to the accumulation of coal, *Lepidodendra*, when present, appear under the same conditions with *Sigillariæ*, the outer bark being converted into shining coal, and the scalariform axis appearing as mineral charcoal of a more loose and powdery quality than that derived from *Sigillaria*. On the planes of lamination of the coal the furrowed bark of old trunks can scarcely be distinguished from that of old *Sigillariæ*.

10. *Lepidophloios*.—Under this generic name, established by Sternberg, I propose to include those Lycopodiaceous trees of the Coal-measures which have thick branches, transversely elongated leaf-scars, each with three vascular points and placed on elevated or scale-like protuberances, long one-nerved leaves, and large lateral strobiles in vertical rows or spirally disposed. Their structure resembles that of *Lepidodendron*, consisting of a *Sternbergia* pith, a slender axis of large scalariform vessels, giving off from its surface bundles of smaller vessels to the leaves, a very thick cellular bark, and a thin dense outer bark, having some elongated cells or bast tissue on its inner side.

Regarding *L. laricinum* of Sternberg as the type of the genus, and taking in connexion with this the species described by Goldenberg, and my own observations on numerous specimens found in Nova Scotia, I have no doubt that *Lomatophloios crassicaulis* of Corda, and other species of that genus described by Goldenberg, *Ulodendron* and *Bothrodendron* of Lindley, *Lepidodendron ornatissimum* of Brongniart, and *Halonia punctata* of Geinitz all belong to this genus, and differ from each other only in conditions of growth and preservation. Several of the species of *Lepidostrobus* and *Lepidophyllum* also belong to *Lepidophloios*.

The species of *Lepidophloios* are readily distinguished from *Lepidodendron* by the form of the areoles, and by the round scars on the stem, which usually mark the insertion of the strobiles, though in barren stems they may also have produced branches; still the fact of my finding the strobiles *in situ* in one instance, the accurate resemblance which the scars bear to those left by the cones of the Red Pine when borne on thick branches, and the actual impressions of the radiating scales in some specimens, leave no doubt in my mind that they are usually the marks of cones; and the great size of the cones of *Lepidophloios* accords with this conclusion.

The species of *Lepidophloios* are numerous, and individuals are quite abundant in the Coal-formation, especially toward its upper part. Their flattened bark is frequent in the coal-beds and their roofs, affording a thin layer of pure coal, which sometimes shows the peculiar laminated or scaly character of the bark when other characters are almost entirely obliterated. The leaves also are nearly as abundant as those of *Sigillaria* in the coal-shales. They can readily be distinguished by their strong angular midrib.

I figure, in illustration of the genus, all the parts known to me of *L. Acadianus*, and characteristic specimens of other species. One of these, *L. parvus*, is characteristic of the Upper Coal-formation. (*Vide* Plate X. & Plate XI. fig. 51.)

11. *Cordaites* or *Pychnophyllum*.—This plant is represented in the Coal-formation chiefly by its broad striated leaves, which are extremely abundant in the coal and its associated shales. Some thin coals are indeed almost entirely composed of them. The most common species is *C. borassifolia*, a plant which Corda has shown to have a simple stem with a slender axis of scalariform vessels resembling that of *Lepidophloios*; for this reason, notwithstanding the broad and parallel-veined leaves, I regard this genus as belonging to *Lycopodiaceæ* or some allied family. It must have been extremely abundant in the Carboniferous swamps; and, from the frequency of its being covered with *Spirorbis*, I think it must either have been of more aquatic habit than most of the other plants of the Coal-formation, or that its leaves must have been very durable. While the leaves are abundant, the stems are very rare. I infer that they were usually low and succulent. Much of the tissue found in the coal, which I have called "epidermal," probably belongs to leaves of *Cordaites*.

In the Upper Coal-formation there is a second species, distinguished by its simple and uniform venation. This I have named *C. simplex*.

12. *Sporangites*.—To avoid the confusion which envelopes the classification of Carpolites, I have used the above name for rounded spore-cases of *Lepidodendron* and allied plants, which are very frequent in the coal. A smooth round species like a mustard-seed, is excessively abundant in the Lower Carboniferous at Horton, and probably belongs to *Lepidodendron corrugatum*, with which it is associated. A species covered with papillæ, *S. papillata*, constitutes nearly the whole of some layers in coal 12, group xix. of the preceding Section.

I have no indication as to the plant to which it may belong, except that it is associated with *Cordaites*. (Figs. 80 & 81, Pl. XII.)*

13. *Tissues in the Mineral Charcoal.*—On these I have little to add to the statements in my paper of 1859, "On the Vegetable Structures in Coal"†. These tissues may be arranged as follows:—

a. *Bast tissue, or elongated cells from the liber or inner bark of* Sigillariæ *and* Lepidodendron, *but especially of the former.*—This kind of tissue is abundant in a calcified state in the shales associated with the coals, and also as mineral charcoal in the coals themselves, and in the interior of erect *Sigillariæ*. It is the kind of tissue figured by Brongniart as the inner layer of bark in *Sigillaria elegans*, and very well described by Binney (Quart. Journ. Geol. Soc. vol. xviii.) as "elongated tissue or utricles." Under the microscope many specimens of it closely resemble the imperfect bast tissue of the inner bark of *Pinus strobus* and *Thuja occidentalis*; and like this it seems to have been at once tough and durable, remaining in fibrous strips after the woody tissues had decayed. It is extremely abundant at the Joggins in the mineral charcoal of the smaller coal-seams. It is often associated with films of structureless coal, which represent the dense cellular outer bark which, in the trunk of *Sigillaria*, not only surrounded this tissue, but was intermixed with it. (Fig. 62, Pl. XII.)

b. *Vascular bundles of Ferns.*—These may be noticed by all close observers of the surfaces of coal, as slender hair-like fibres, sometimes lying separately, in other cases grouped in bands half an inch or more in diameter, and imbedded in a loose sort of mineral charcoal. When treated with nitric acid, each bundle resolves itself into a few scalariform vessels surrounded with a sheath of woody fibres, often minutely porous. This structure is precisely that of macerated fern-stipes; but, as already stated, there may have been some other coal-plants whose leaves presented similar bundles. As stated in my former paper "On the Vegetable Structures in Coal," this kind of tissue is especially abundant in the coarse and laminated portions of the coal, which we know on other evidence to have been made up, not of trunks of trees, but of mixed herbaceous matters. (Pl. XII. fig. 67.)

c. *Scalariform vessels.*—These are very abundant in the mineral charcoal, though the coarser kinds have been crushed and broken in such a manner that they usually appear as mere débris. The scalariform vessels of *Lepidodendron*, *Lepidophloios*, and *Stigmaria* are very coarse and much resemble each other. Those of ferns are finer, and sometimes have a reticulated structure. Those of *Sigillaria* are much finer and often have the aspect of wood-cells with transversely elongated pores like those of *Cycas*. Good examples of these are figured in the paper already referred to. (See also Plate XI. figs. 54, &c.)

d. *Discigerous wood-cells.*—These are the true bordered pores characteristic of *Sigillaria*, *Calamodendron*, and *Dadoxylon*. In the two former genera the disks or pores are large and irregularly arranged, either in one row or several rows. In the latter case they are sometimes regularly alternate and contiguous. In the genus *Dadoxylon* they are of smaller size and always regularly contiguous in two or more rows, so as to present an hexagonal areolation. Discigerous structures of *Sigillaria* and *Calamodendron* are very abundant in the coal, and numerous examples were figured in my former paper. I have indicated by the name *Reticulated Tissue* certain cells or vessels which may either be reticulated scalariform vessels, or an imperfect form of discigerous tissue. I believe them to belong to *Stigmaria* or *Calamodendron*. (Figs. 57 & 68, Pl. XII.)

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* It much resembles the spore-cases of *Flemingites gracilis*, as figured by Carruthers, 'Geol. Mag.' vol. ii. I suppose this to be a strobile of *Lepidophloios*.

† Quart. Journ. Geol. Soc. February 1860.

e. *Epidermal tissue*.—This is a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits. I have ascertained that the structures in question occur in the leaves and stipes of *Cordaites* and ferns, and in the outer coat of *Carpolites* and *Sporangites*. With this I may include the obscure and thick-walled cellular tissue of the outer bark of *Sigillaria* and *Lepidodendron* and other trees, which, though usually consolidated into compact coal, sometimes exhibits its structure.

I would here emphatically state that all my observations at the Joggins confirm the conclusion, which I arrived at many years ago from the study of the coals of Pictou and Sydney, that the layers of clear shining coal (pitch or cherry coal) are composed of flattened trunks of trees, and that of these usually the bark alone remains; further that the lamination of the coal is due to the superposition of layers of such flattened trunks alternating with the accumulations of vegetable matter of successive years, and occasionally with fine vegetable muck or mud spread over the surface by rains or by inundations. In connexion with this, it is to be observed that the density and *impermeability* of cortical tissues not only enable them to endure after wood has perished or been resolved into bits of charcoal, but render them less liable than the wood to mineral *infiltration*.

14. *Rate of Growth of Carboniferous Plants*.—Very vague statements are often made as to the supposed rapid rate of growth of plants in the Carboniferous period. Perhaps the most trustworthy facts in relation to this subject are those which may be obtained from the coniferous trees. In some of these (for instance, *Dadoxylon materiarium*, *D. annulatum*, and *D. antiquius*) the rings of growth, which were no doubt annual, are distinctly marked. On measuring these in a number of specimens, and comparing them with modern species, I find that they are about equal in dimensions to those of the Balsam-Fir or the Yellow Pine of America. Assuming, therefore, similarity in habit of growth and extent of foliage to these species, we may infer that, in regard to coniferous trees, the ordinary conditions of growth were not dissimilar from those of Eastern America in its temperate regions at present. When, however, we compare the ferns and *Lycopodiaceæ* of the Coal-formation with those now growing in Eastern America, we see, in the much greater dimensions and luxuriance of the former, evidence of a much

more moist and equable climate than that which now subsists; so that we may suppose the growth of such plants to have been more rapid than it is at present. These plants would thus lead us to infer a warm and insular climate, perhaps influenced by that supposed excess of carbonic acid in the atmosphere, which, as Tyndall and Hunt inform us, would promote warmth and moisture by impeding terrestrial radiation. With this would also agree the fact that the Conifers have woody tissues resembling those of the pine trees of the milder climates of the southern hemisphere at present.

If we apply these considerations to *Sigillaria*, we may infer that the conditions of moisture and uniformity of temperature favourable to ferns and *Lycopodiaceæ* were also favourable to these curious plants. They must have been perennial: and the resemblance of their trunks to those of Cycads, together with their hard and narrow leaves, would lead us to infer that their growth must have been very slow. A similar inference may be drawn from the evidences of very slow and regular expansion presented by the lower parts of their stems. On the other hand, the distance, of a foot or more, which often intervenes between the transverse rows of scars, marking probably annual fructification, would indicate a more rapid rate of growth. Further, it may be inferred, from the structure of their roots and of their thick inner bark, that these, as in Cycads, were receptacles for great quantities of starch, and that the lives of these plants presented alternations of starch-accumulation and of expenditure of this in the production of leaves, wood, and abundant inflorescence. They would thus, perhaps for several years, grow very slowly, and then put forth a great mass of fructification, after which perhaps many of the individuals would die, or again remain for a long time in an inactive state. This view would, I think, very well harmonize with the structure of these plants, and also with the mode of their entombment in the coal.

From the manner of the association of Calamites with erect *Sigillariæ*, I infer that the former were, of all the plants of the Coal-formation, those of most rapid dissemination and growth. They appear to have first taken possession of emerging banks of sand and mud, to have promoted the accumulation of sediment on inundated areas, and to have protected the exposed margins of the forests of *Sigillariæ*.

In applying any conclusions as to the rate of growth of Carboniferous plants to the accumulation of coal, we must take into account the probable rate of decay of vegetable matter. When we consider the probable wetness of the soils on which the plants which produced the coal grew, the density of the forests, and the possible excess of carbonic acid in the atmosphere of these swamps, we must be prepared to admit that, notwithstanding the warmth and humidity, the conditions must have been favourable to the preservation of vegetable matter. Still the hollow cylinders of bark, the little fragments of decayed wood in the form of mineral charcoal, and the detached vascular bundles of ferns, testify to an enormous amount of decay, and show that, however great the accumulation of coal, it represents only a fraction of the vegetable matter which was actually produced. It has been estimated that it would require eight feet of compact vegetable matter to produce one foot of coal*; but if we reckon the whole vegetable matter actually produced in the process, I should suppose that five times that amount would be far below the truth, even in the most favourable cases; while there is evidence that in the Carboniferous period many forests may have flourished for centuries without producing an inch of coaly matter.

15. *Bivalve Shells.*—All the Lamellibranchiate shells, which are so numerous in some of the shales and bituminous limestones of the Joggins that some of the beds may be regarded as composed of them, belong to one generic or family group. They are the so-called Modiolas, Unios, or Anodons of authors. I proposed for them some years ago the generic name of *Naiadites,* and described six species from the Coal-measures of Nova Scotia, stating my belief that they are allied to *Unionidæ*, and that their nearest analogue may be the genus *Bysso-anodonta* of D'Orbigny, found in the River Papana†. Mr. Salter, however, to whom I sent specimens, regards these shells as belonging to his new genera *Anthracomya* and *Anthracoptera,* the former being supposed to be allied to *Myadæ*‡. More recently Gümbel and Geinitz have described similar shells from Thuringia as belonging to the genera *Unio* and *Anodon*, and regard my *Naiadites carbonarius* (*Anthracoptera carbonaria* of Salter) as a *Dreissena*§. As these shells swarmed in the waters of the Coal-formation estuaries or lagoons, facts tending to the elucidation of their habits and affinities are important with reference to the coal; I would therefore make the following remarks in relation to them:—

(1) Under the microscope, the shells of the thicker species, as *Naiadites carbonarius,* present an internal lamellar and subnacreous layer, a thin layer of vertical prismatic shell, and an epidermis—these structures being entirely similar to those of *Unionidæ*. In the thinner species, as in *N. lævis,* only the prismatic coat appears, and in this the prisms are in some instances placed obliquely. These thin shells, however, show evidence of an epidermis. (2) The ligament was external, there seem to have been no teeth, the shell was closed posteriorly; but there are indications of a byssal sinus. Mr. Salter describes the epidermis as wrinkled posteriorly; but this, with the exception of the rings of growth, appears to me to result from pressure. The shells are equivalve, and have the external aspect of *Unionidæ* or *Mytilidæ*. (3) I know of no instance in Nova Scotia of the occurrence of these shells in the strictly marine limestones, nor have any properly marine forms of Mollusca been found with *Naiadites* in the Coal-measures. (4) The mode of their occurrence precludes the idea that they were burrowers, but favours the belief that they were attached by a byssus to sunken or floating timber. On the whole I think that the balance of probability is in

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* Dana's Manual, p. 367.
† Supplement to Acadian Geology, 1860.
‡ Quart. Journ. Geol. Soc. vol. xix. p. 79.
§ Neues Jahrbach, 1864. Geological Magazine, May 1865.

favour of the conclusion that they were brackish-water or fresh-water shells, allied to *Mytilidæ* or to embryonic *Unionidæ*.

16. *Spirorbis carbonarius.*—This little shell, which I described as a *Spirorbis* as long ago as 1845*, is apparently not specifically distinct from *Microconchus carbonarius* of the British coal-fields. Its microscopic structure is identical with that of modern *Spirorbes*, and shows that it is a true worm-shell. It is found throughout the Coal-formation, attached to plants and to shells of *Naiadites*, and must have been an inhabitant of enclosed lagoons and estuaries. Its occurrence on *Sigillariæ* has been used as an argument in favour of the opinion that these trees grew in sea-water; but, unfortunately for that conclusion, the *Spirorbis* is often found on the inside of *Sigillaria*-bark, showing that this had become dead and hollow. Beside this, the same kind of evidence would prove that *Lepidodendra*, *Cordaites*, and Ferns were marine plants. *Spirorbes* multiply fast and grow very rapidly: and these little shells no doubt took immediate possession of submerged vegetation, just as their modern allies cover fronds of *Laminaria* and *Fucus*.

As I have not met with a description of this little shell, I may state that it is dextral, with 2½ to 3 turns. It is attached throughout its length, and when not compressed presents a somewhat deep umbilicus. It is closely marked with beaded or unequal transverse ridges. It has when young a close resemblance to *Sp. caperatus*, M'Coy, from the Carboniferous Limestone of Ireland; but this species has only two turns, and is sinistral.

17. *Crustacea.*—It appears in the table above that as many as fourteen beds of coal exhibit in their roofs shells of minute Entomostraca of the genera *Cythere* and *Bairdia*; and these occur in such quantities that considerable beds of shale and bituminous limestone are filled with their valves. Professor Jones regards the species as marine or brackish-water: and the same remark will, I presume, apply to the crustacean *Diplostylus Dawsoni*, and a fragment of *Eurypterus* described by Mr. Salter from Coal no. 8 of Division 4 of the Section. Of the small Entomostracans there are several species, which Professor Jones has now in his hands for determination. No Estherians have yet been found in the Coal-formation of Nova Scotia; but I have specimens of *Leaia Leidyi* from the Lower Carboniferous of Plaister Cove, and an undetermined *Estheria* from the same horizon at Horton Bluff.

It is to be observed that *Naiadites*, *Spirorbis*, and *Cythere* constantly occur associated in the same beds; and the conclusions as to habitat applicable to any one of these genera must apply to all.

18. *Fishes.*—Remains of fishes occur in connexion with eighteen of the coal-beds at the Joggins, usually in the roof-shales, though detached scales, teeth, spines, or coprolites are of occasional though rare occurrence in the coal itself, especially where the latter passes into coarse coal or carbonaceous shale. One thin bed, no. 6 of Division 4 of the Section, is full of remains of small fishes. It is hard and laminated, and roofed with a calcareous bed full of remains

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* Quart. Journ. Geol. Soc. vol. i. p. 326.

of aquatic animals. It has a true Stigmarian underclay. I suppose it to have been a swamp or forest submerged and occupied by fishes while its vegetation was still standing. It contains remains of fishes of the genera *Ctenoptychius*, *Diplodus*, *Rhizodus*, and *Palæoniscus*. It also contains *Cythere*, *Naiadites*, and *Spirorbis*. In the other beds which contain fish-remains, most of these consist of small Lepidoganoids, but there are occasional teeth and scales of large species of *Rhizodus*, and also teeth and scales of Selachian fishes of considerable size.

19. *Land-animals.*—The Coal-formation of Nova Scotia has afforded the remains of eight species of Reptiles or Batrachians, belonging to the genera *Hylonomus*, *Baphetes*, *Dendrerpeton*, *Hylerpeton*, and *Eosaurus*; of one Myriapod, *Xylobius sigillariæ*; of one land snail, *Pupa vetusta*; and of one insect. All of these, except one of the reptiles, have been found at the Joggins. I have nothing in regard to them to add to what I have already published in my Memoir on 'Air-breathers of the Coal Period.'

V. APPENDIX.

Descriptive List of Carboniferous Plants found in Nova Scotia and New Brunswick.

[Abridged and corrected from "Synopsis of the Carboniferous Flora of Nova Scotia," Can. Nat. vol. viii.] *

DADOXYLON, Unger.

1. DADOXYLON ACADIANUM, spec. nov. Pl. V. figs. 4–6.

Large trees, usually silicified or calcified, with very wide wood-cells, having three or more rows of small hexagonal areoles, each enclosing an oval pore; cells of medullary rays one-third of breadth of wood-cells, and consisting of twenty or more rows of cells superimposed in two series. Rings of growth indistinct.

M. C.†, Joggins, Port Hood, Dorchester (*J. W. D.*).

2. D. MATERIARIUM, spec. nov. Pl. V. figs. 7–9.

Wood-cells less wide than those of the last; two to rarely four rows of hexagonal disks. Medullary rays very numerous, with twenty or more rows of cells superimposed in one series. Rings of growth slightly marked. Approaches in the character of its woody fibre to *D. Brandlingii*; but the medullary rays are much longer. Some specimens show a large Sternbergian pith, with transverse partitions‡. Vast numbers of trunks of this species occur in some sandstones of the Upper Coal-formation.

M. and U. C., Joggins, Malagash, Pictou, &c. (*J. W. D.*); Glace Bay (*H. Poole*); Miramichi (*G. F. Matthew*).

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* The illustrations are principally from photographs by my son George M. Dawson, and for the sake of economy have been confined to small and characteristic portions of the specimens.

† U. C., M. C., and L. C., indicate the Upper, Middle, and Lower Coal-formations.

‡ Canadian Naturalist, 1857.

3. D. ANTIQUIUS, spec. nov. Pl. V. figs. 1–3.

Wood-cells narrow, thick-walled, two to three rows of pores. Medullary rays of three or four series of cells with twenty or more superimposed, nearly as wide as the wood-cells. Rings of growth visible. This species would belong to the genus *Palæoxylon* of Brongniart, and is closely allied to *D. Withami*, L. and H., which, like it, occurs in the Lower Coal-measures.

L. C., Horton (*Dr. Harding*).

4. D. ANNULATUM, spec. nov. Pl. V. figs. 10–13.

Wood-cells with two or three rows of hexagonal disks. Medullary rays of twenty or more rows of cells superimposed, in two series. Wood divided into distinct concentric circles, alternating with layers of structureless coal representing cellular tissue or very dense wood. A stem 6 inches in diameter has fourteen to sixteen of these rings, and a pyritized pith about 1 inch in diameter. This is probably generically distinct from the preceding species.

M. C., Joggins (*Sir W. E. Logan*; *J. W. D.*).

ARAUCARITES, Unger.

ARAUCARITES GRACILIS, spec. nov. Pl. VI. fig. 14.

Branches slender, 0·2 inch in diameter, with scaly, broad leaf-bases. Branchlets pinnate, numerous, very slender, with small, acute, spirally disposed leaves.

U. C., Tatamagouche (*J. W. D.*).

SIGILLARIA, Brongn.

1. SIGILLARIA (FAVULARIA) ELEGANS, Brongn. Pl. VII. fig. 26.

Abundant, especially in the roofs of coal-seams. *S. hexagona* includes old trunks of this species. Young branches have scars of an elliptical form like those of *S. Serlii*.

M. C., Joggins (*J. W. D.*): Sydney (*R. Brown*).

2. S. (FAV.) TESSELLATA, Brongn.

M. C., Joggins and Picton (*J. W. D.*); Sydney (*R. Brown*).

3. S. (RHYTIDOLEPIS) SCUTELLATA, Brongn. Pl. VI. fig. 25.

M. and U. C., Joggins (*Lyell*; *J. W. D.*).

4. S. (RH.) SCHLOTHEIMIANA, Brongn.

M. C., Joggins (*Lyell*; *J. W. D.*).

5. S. (RH.) SAULLII, Brongn.

M. C., Sydney (*R. Brown*); Joggins (*Lyell*; *J. W. D.*).

6. S. BROWNII, Dawson (Quart. Journ. Geol. Soc. vol. x.). Pl. VI. figs. 15–19.

M. C., Joggins (*J. W. D.*).

7. S. RENIFORMIS, Brongn.

M. C., Joggins (*Lyell*; *J. W. D.*); Sydney (*R. Brown*).

8. S. LÆVIGATA, Brongn.
M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

9. S. PLANICOSTA, spec. nov. Pl. VI. fig. 21.

Scars half hexagonal above, rounded below; lateral vascular impressions elongate; central small, punctiform. Ribs 1·1 inch broad, smooth externally, longitudinally striated on the ligneous surface. Slight transverse wrinkles between the scars, which are distant from each other about an inch. Allied to *S. lævigata*, but with very thin bark.
M. C., Sydney (*R. Brown*).

10. S. CATENOIDES, spec. nov. Pl. VI. fig. 22.

Cortical surface unknown; ligneous surface with puncto-striate ribs 1·1 inch in breadth, and with single oval scars half an inch long, and an inch distant from centre to centre. A very large tree. Perhaps, if its cortical surface were known, it might prove to be a large *Syringodendron*.
M. C., Joggins (*J. Smith*); Sydney (*R. Brown*).

11. S. STRIATA, spec. nov. Pl. VI. fig. 23.

Ribs prominent, coarsely striate, 0·35 inch wide. Scars nearly as wide as the ribs, rounded, hexagonal, 1 inch distant; lateral vascular marks narrow, central large. On the ligneous surface scars single, round, oblong; bark very thin.
M. C., Joggins (*J. W. D.*).

12. S. ——?

A small erect stem, somewhat like *S. flexuosa*.
M. C., Joggins (*J. W. D.*).

13. S. (CLATHRARIA) MENARDI, Brongn.
M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

14. S. (ASOLANUS) SYDNENSIS, spec. nov. Pl. VII. fig. 28.

Ribs obsolete; cortical and ligneous surfaces striate; vascular scars two, elongate longitudinally, and alike on cortical and ligneous surfaces; scars 1·1 inch distant, in rows 0·6 inch distant. Stigmarian roots, same with variety *h* of *Stigmaria*, as described below.
M. C., Sydney (*R. Brown*).

15. S. ORGANUM, L. & H.
M. C., Sydney (*R. Brown*).

16. S. ELONGATA, Brongn.
M. C., Sydney (*R. Brown*).

17. S. FLEXUOSA, L. & H.
M. C., Sydney (*R. Brown's list in 'Acadian Geology'*).

18. S. PACHYDERMA, L. & H.
M. C., Sydney (*R. Brown's list*).

19. S. (FAV.) BRETONENSIS, spec. nov. Pl. VII. fig. 27.

Like *S. tessellata*, but areoles more hexagonal, bark thin and smooth on both sides, and furrow above the scars arcuate and with a central punctiform elevation.

M. C., Sydney (*R. Brown*).

20. S. EMINENS, spec. nov. Pl. VI. fig. 24.

Like *S. obovata*, Lesqx., but with narrower ribs, and larger and less distant areoles, each with a slight groove above.

M. C., Sydney (*R. Brown*).

21. S. DOURNANSII, Brongn.

M. C., Joggins (*J. W. D.*).

22. S. KNORRII, Brongn.

M. C., Sydney (*R. Brown*).

SYRINGODENDRON, Brongn.

Obscure specimens, referable to a narrow-ribbed species of this genus, occur in the Lower Carboniferous beds at Horton and Onslow.

STIGMARIA, Brongn.

STIGMARIA FICOIDES, Brongn. Pl. XII. fig. 83–87.

Under this name I place all the roots of *Sigillariæ* occurring in the Carboniferous rocks of Nova Scotia. They belong, without doubt, to the different species of Sigillarioid trees; but it is at present impossible to determine to which; and the specific characters of the *Stigmariæ* themselves are, as might be anticipated, evanescent and unsatisfactory. The varieties which occur in Nova Scotia, discarding mere difference of preservation, may be arranged as follows:—

Var. *a*. Areoles large, distant; bark more or less smooth. This is the most common variety, and extends throughout the Coal-formation.

Var. *b*. Areoles large, separated by waving grooves of the bark.

Var. *c*. Similar, but ridges as well as furrows between the areoles; var. *undulata* of Goeppert.

Var. *d*. Areoles small, separated by waving grooves.

Var. *e*. Areoles moderate, in vertical or diagonal furrows separated by ridges; var. *sigillarioides* of Goeppert.

Var. *f*. Areoles small; bark finely netted with wrinkles or striæ.

Var. *g*. Areoles surrounded by radiating marks, giving a star-like form: var. *stellata* of Goeppert. The only specimen I have seen was found by Dr. Harding in the Lower Carboniferous Coal-measures of Horton.

Var. *h*. Areoles small, or obscure and infrequent. Surface covered with fine uneven striæ. My specimens were collected by Mr. Brown in the Middle Coal-measures at Sydney.

Var. *i*. Areoles narrow, elongate, bark smooth or striate.

Var. *k*. *alternans*, with areoles in double rows on broad ribs separated by deep furrows. Probably old furrowed roots.

Var. *l. Knorroides.* Prominent bosses or ridges instead of areoles. These are imperfectly preserved specimens.

The varieties *a, b, c, e, i,* have been seen attached to trunks of *Sigillariæ* of the group distinguished by broad and prominent ribs—*Sigillaria* proper of the above arrangement. *Stigmariæ,* like *Sigillariæ,* are exceedingly abundant in the Middle Coal-measures, and are comparatively rare in the Lower Carboniferous and newer Coal-formations.

CALAMODENDRON, Brongn.

1. CALAMODENDRON APPROXIMATUM, Brongn. Pl. VII. fig. 31.

This plant is evidently quite distinct from *Calamites* proper. The Calamite-like cast is a pith or internal cavity, surrounded by a thick cylinder of woody tissue consisting of scalariform vessels and woody fibres with one row of round pores; external to this is a bark of cellular and bast tissue. The structure appears to be allied to that of *Sigillaria,* and is one of the most common in the beds of bituminous coal.

M. C., Sydney (*R. Brown*); M. C., Joggins, Pictou (*J. W. D.*); Coal Creek (*C. B. Matthew*).

2. C. OBSCURUM, spec. nov. Pl. VII. fig. 31 *d.*

This is a Calamite-like fragment found in a block of Sydney coal, in the state of mineral charcoal. The external markings are obscure, but the structure is well preserved. It differs from the last in having large ducts with many rows of pores, or reticulated instead of scalariform vessels. This is perhaps a Calamite.

M. C., Sydney (*J. W. D.*).

CYPERITES, L. & H.

CYPERITES —— ?

These elongate linear leaves have two or three ribs, and the central band between the ribs raised above the margin; one species has been seen attached to *Sigillaria Schlotheimiana.*

The leaves of *Sigillaria elegans* are different, being as broad as the areoles of the stem, and with several parallel veins.

Middle and upper coals, everywhere.

ANTHOLITHES, Brongn.

1. ANTHOLITHES RHABDOCARPI, spec. nov. Pl. VII. fig. 30.

Stem short, interruptedly striate, with two rows of crowded ovate fruits, and traces of floral leaves. Fruits half an inch long, striated longitudinally, attached by short peduncles.

M. C., Grand Lake (*C. F. Hartt*).

2. A. PYGMÆA, spec. nov. Pl. VII. fig. 30 *c.*

Rhachis 1 inch thick, rugose; two rows of opposite flowers, each showing four lanceolate striate floral leaves, two outer and two inner.

M. C., Joggins (*J. W. D.*).

3. A. SQUAMOSA, spec. nov. Pl. VII. fig. 29.

Rhachis thick, coarsely rugose, with two rows of closely placed cones or scaly fruits.

U. C., Pictou (*J. W. D.*).

4. A. ——?, spec. nov.

Indistinct, but apparently different from those above described.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

TRIGONOCARPUM, Brongn.

1. TRIGONOCARPUM HOOKERI, Dawson, Quart. Journ. Geol. Soc. vol. xvii.

M. C., Mabou (*J. W. D.*).

2. T. SIGILLARIÆ, spec. nov. Pl. XII. fig. 76.

Ovate, $\frac{1}{4}$ inch long; testa smooth, or rugose longitudinally, acuminate, two-edged. Found in erect trunks of *Sigillariæ* in large numbers.

M. C., Joggins (*J. W. D.*).

3. T. INTERMEDIUM, spec. nov. Pl. XII. fig. 78.

Allied to *T. olivæformis*, but larger and more elongated.

M. C., Joggins, (*J. W. D.*).

4. T. AVELLANUM, spec. nov. Pl. XII. fig. 77.

Allied to *T. ovatum*, L. & H.; three-ribbed, size and form of a filbert.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

5. T. MINUS, spec. nov. Pl. XII. fig. 75.

Half the size of *T. Hookeri*, and similar in form.

M. C., Joggins (*J. W. D.*).

6. T. ROTUNDUM, spec. nov.

Small, round-ovate, slightly pointed.

M. C., Joggins (*J. W. D.*).

7. T. NŒGGERATHI, Brongn.

Newer Coal-formation, Pictou (*J. W. D.*).

RHABDOCARPUS, Goepp. and Bergm.

1. RHABDOCARPUS ——?, spec. nov.

Ovate acuminate, less than half an inch long.

M. C., Joggins (*J. W. D.*).

2. R. INSIGNIS, spec. nov. Pl. XII. fig. 69.

1·5 inch long, ovate, smooth, with about seven ribs on one side, and the intervening surface obscurely striate. The nature of this fossil is perhaps doubtful; but if a fruit, it is the largest I have seen in the Coal-formation.

U. C., Pictou (*J. W. D.*).

Calamites, Suckow.

1. Calamites Suckovii, Brongn.

This species is one of the most common in an erect position. It has verticillate branchlets, with pinnate linear leaflets.

M. C., Sydney (*R. Brown*); Joggins (*Lyell; J. W. D.*); Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*); Coal Creek (*C. B. Matthew*).

2. C. Cistii, Brongn.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Coal Creek (*C. B. Matthew*).

Often found erect. Its leaves are verticillate, simple, linear, striate, apparently one-nerved, and 3 inches long.

3. C. cannæformis, Brongn.

M. C., Joggins (*Lyell; J. W. D.*); Sydney (*R. Brown*).

4. C. ramosus, Artis.

Possibly a variety of *C. Suckovii.*

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

5. C. Voltzii, Brongn. (*C. irregularis*, L. & H.)

M. C., Joggins (*J. W. D.*).

Often erect; has large irregular adventitious roots. This species is regarded by Brongniart as probably belonging to *Calamodendron*.

6. C. dubius, Artis.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.; Logan*); U. C., Pictou (*J. W. D.*).

7. C. Nova-scotica, spec. nov. Pl. XII. fig. 89.

M. C., Joggins (*J. W. D.*).

Ribs equal, less than a line wide, striated longitudinally. Joints obscurely marked, and with circular areoles separated by the breadth of three to four ribs. Bark of moderate thickness.

8. C. nodosus, Schloth.

This species has long slender branchlets, with close whorls of short rigid leaves.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

9. C. arenaceus (?), Jäger.

This species is mentioned with doubt in Lyell's list.

Equisetites, Sternberg.

Equisetites curta, spec. nov. Pl. XII. fig. 88.

Short thick stems, enlarging upward, and truncate above; joints numerous; sheaths as long as the joints, with unequal acuminate keeled points. Lateral branches or fruit with longer leaf-like points. Has the characters of *Equisetites*; but its affinities are quite uncertain.

M. C., Sydney (*R. Brown*).

Asterophyllites, Brongn.

1. Asterophyllites foliosa, L. & H.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

2. A. equisetiformis, L. & H.

M. C., Sydney (*R. Brown*); Pictou (*J. W. D.*).

3. A. grandis, Sternberg?

The specimens resemble this species, but are not certainly the same. Logan's specimens have terminal spikes of fructification.

M. C., Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Sydney (*Bunbury*).

4. Asterophyllites, sp.

A species with tubercles (fruit) in the axils is mentioned in Lyell's list as from Sydney. I have not seen it, but have a specimen from Mr. Brown similar to *A. tuberculata*, Sternberg, which may be the same.

5. A. trinervis, spec. nov. Pl. XIII. fig. 90.

Main stem smooth, delicately striate, with leaves at the nodes. Branches delicately striate, with numerous whorls of linear nearly straight leaves, 0·5 inch long, twenty or more in a whorl, and showing two lateral nerves in addition to the median nerve. This and *A. equisetiformis* would be placed by some authors in *Annularia*.

M. C., Sydney (*R. Brown*).

Annularia, Sternberg.

Annularia galioides, Zenker.

M. C., Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*); Bay de Chaleur (*Logan*); Sydney (*R. Brown*).

Sphenophyllum, Brongn.

1. Sphenophyllum emarginatum, Brongn.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Pictou (*J. W. D.*).

2. S. longifolium, Germar.

U. C., Pictou (*J. W. D.*); M. C., Sydney (*R. Brown*).

3. S. saxifragifolium, Sternberg.

Elongate much-forked variety, closely allied to *S. bifurcatum* Lesquereux.

Bay de Chaleur (*Logan*).

4. S. Schlotheimii, Brongn.

M. C., Sydney (*Bunbury*).

5. S. erosum, L. and H.

M. C., Sydney (*Bunbury*).

The last two species are regarded by Geinitz as varieties of *S* *emarginatum*. A specimen of the last-named species in Sir William

Logan's collection shows a woody jointed stem like that of *Asterophyllites,* giving off branches at the joints; these again branch and bear whorls of leaves. The stem shows under the microscope a single bundle of reticulated or scalariform vessels like those of some ferns, and also like those of *Tmesipteris,* as figured by Brongniart. This settles the affinities of these plants as being with ferns or with *Lycopodiaceæ.*

PINNULARIA, L. & H.

1. PINNULARIA CAPILLACEA, L. & H.

M. C., Sydney (*R. Brown*).

2. P. RAMOSISSIMA, spec. nov.

More slender and ramose than the last.
M. C., Joggins (*J. W. D.*).

3. P. CRASSA, spec. nov.

Branching like *P. capillacea,* but much stronger and coarser.
L. C., Horton (*C. F. Hartt*).

All these are apparently branching fibrous roots, of soft cellular tissue with a thin epidermis and slender vascular axis. Perhaps they are roots of *Asterophyllites.*

Genus NŒGGERATHIA, Sternberg.

1. NŒGGERATHIA DISPAR, spec. nov. Pl. XIII. fig. 91.

A remarkable fragment of a leaf, with a petiole nearly 3 inches long, and a fourth of an inch wide, spreading abruptly into a lamina, one side of which is much broader than the other, and with parallel veins running up directly from the margin as from a marginal rib. It appears to be doubled in at both edges, and is abruptly broken off. It seems to be a new species; but of what affinities, it is impossible to decide.

Bay de Chaleur (*Sir W. E. Logan*).

2. N. FLABELLATA, L. & H.

M. C., Sydney (*R. Brown*).

CYCLOPTERIS, Brongn.

(including *Cyclopteris* proper, and subgenera *Aneimites,* Daws., and *Neuropteris,* Brongn.).

1. CYCLOPTERIS HETEROPHYLLA, Goeppert.

M. C. and U. C., Joggins (*J. W. D.*).

2. C. (ANEIMITES) ACADICA, Dawson, Quart. Journ. Geol. Soc. vol. xvii. p. 5. Pl. VIII. fig. 32.

Stipe large, striate, branching dichotomously several times. Pinnæ with several broadly obovate pinnules grouped at the end of a slender petiolule, and with dichotomous radiating veins. Fertile pinnæ with recurved petiolules, and borne on the divisions of the main petiole near their origin. This plant might be placed in the genus *Adiantites,* Brongn., but for the fructification, which allies it with such ferns as *Aneimia*. It has a very large frond, the main petiole being sometimes 3 inches in diameter, and 2 feet long before branching. Flattened petioles have sometimes been mistaken for *Cordaites* and *Schizopteris*. It is a characteristic plant of the Lower Coal-measures.

L. C., Horton (*C. F. Hartt*); Norton Creek, N.B. (*G. F. Matthew*).

3. C. OBLONGIFOLIA, Goeppert.

A little larger and coarser than Goeppert's figure.
U. C., Picton (*J. W. D.*).

4. C. (NEUROPTERIS) OBLIQUA, Brongn.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

5. C. (?NEUROPTERIS) INGENS, L. & H.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

6. C. OBLATA, L. & H.

M. C., Sydney (*R. Brown*).

7. C. FIMBRIATA, Lesquereux.

M. C., Sydney (*R. Brown*).

8. C. HISPIDA, spec. nov. Pl. XIII. fig. 92.

Pinnate; pinnules obovate, diminishing in size towards the point, decurrent on the petiole; veins slender, distant, forking several times; under surface covered with stiff hairs.

M. C., Sydney (*R. Brown*).

9. C. ANTIQUA, spec. nov. Pl. XIII. fig. 95.

L. C., ? Hebert River (*J. W. D.*).

Tripinnate; petioles slender; pinnules oblong, obtuse, decurrent on the petiole, not contiguous. Terminal pinnules much elongated; venation simple, divergent. This plant approaches more nearly to the peculiar species of *Cyclopteris* found in the Devonian, than any of the others I have seen in the Carboniferous.

NEUROPTERIS, Brongn.

1. NEUROPTERIS RARINERVIS, Bunbury.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*).

2. N. PERELEGANS, spec. nov. Pl. XIII. fig. 93.

M. C., Sydney (*R. Brown*).

Resembles *N. elegans*, Brongn., but has narrower pinnules, and nerves less oblique to the midrib. The pinnules were thick and leathery, rough or cellular-netted above, and showing the venation only on the underside.

3. N. CORDATA, Brongn. (and var. *angustifolia*).

The ferns referred to this species are identical with *N. hirsuta* of Lesquereux. They abound in the Middle and Upper Coal-formations, and have larger pinnules than any of the other ferns. A

single terminal pinnule in my collection is 5 inches long. The surface is always more or less hairy.
M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

4. N. Voltzii, Brongn.
A single imperfect specimen like this species, but uncertain.
M. C., Pictou (*J. W. D.*).

5. N. gigantea, Sternb.
M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*).

6. N. flexuosa, Sternb.
M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

7. N. heterophylla, Brongn.
M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

9. N. Loshii, Brongn.
Bay de Chaleur (*Logan*).

10. N. acutifolia, Brongn.
M. C., Sydney (*Lyell's list*).

11. N. conjugata, Goepp.
M. C., Sydney (*Brown's list, Acad. Geol.*).

12. N. attenuata, L. & H.
M. C., Sydney (*l. c.*).

13. N. dentata, Lesq.
M. C., Sydney (*R. Brown*).

14. N. Soretii (Brongn.).
M. C., Sydney (*R. Brown*).

15. N. auriculata, Brongn.
M. C., Sydney (*R. Brown*).

16. N. cyclopteroides, spec. nov. Pl. XIII. fig. 94.
Pinnate; pinnules contiguous or overlapping, obliquely round-ovate, attached at the lower third of the base; nerves numerous, spreading from the point of attachment. Allied to *N. Villiersi*, Brongn.
M. C., Sydney (*R. Brown*).

Odontopteris, Brongn.

1. Odontopteris Schlotheimii, Brongn.
M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*); U. C., Pictou (*J. W. D.*).

2. O. subcuneata, Bunbury.
M. C., Sydney (*R. Brown*).

DICTYOPTERIS, Gutb.

DICTYOPTERIS OBLIQUA, Bunbury.

M. C., Sydney (*R. Brown*).

LONCHOPTERIS, Brongn.

LONCHOPTERIS TENUIS, spec. nov. Pl. XIII. fig. 103.

Pinnate or bipinnate; pinnules contiguous at the base, nearly at right angles to petiole, oblong elongate, obtuse. Network of veins very delicate. Allied to *L. Bricii*, Brongn., but with smaller, more elongate pinnules and finer veins. I suspect this to be a thick-leaved *Pecopteris*, showing a coarse cellular reticulation on the upper surface.

M. C., Sydney (*R. Brown*).

SPHENOPTERIS, Brongn.

1. SPHENOPTERIS MUNDA, spec. nov. Pl. XIII. fig. 97.

Like *S. Dubuissonii*, Brongn., or *S. irregularis*, Sternberg, in habit; but the pinnules are obovate, decurrent, and few-veined.

M. C., Grand Lake (*C. F. Hartt*).

2. S. HYMENOPHYLLOIDES, Brongn.

M. C., Sydney (*R. Brown*); U. C., Joggins (*J. W. D.*).

3. S. LATIOR, spec. nov. Pl. XIII. fig. 98.

Petiole forking at an obtuse angle, slender, tortuous; divisions bipinnate; pinnæ with broad, rounded, confluent pinnules; veins twice forked, with sori in the forks of the veins. In habit like *S. latifolia*, Brongn., *S. Newberryi*, and *S. squamosa*, Lesq.

M. C., Grand Lake (*C. F. Hartt*): U. C., Pictou (*J. W. D.*).

4. S. DECIPIENS, Lesquereux.

M. C., Sydney (*R. Brown*).

5. S. GRACILIS, Brongn.

M. C., Joggins (*J. W. D.*); Grand Lake (*C. F. Hartt*).

6. S. ARTEMISIÆFOLIA, Brongn.

M. C., Grand Lake (*C. F. Hartt*); Sydney (*R. Brown*).

7. S. CANADENSIS, spec. nov. Pl. XIII. fig. 99.

General aspect like *S. Hœninghausi*, but secondary pinnules with a margined petiole, and oblong pinnules divided into three to five obtuse points. It is not unlike *S. marginata*, from the Devonian of St. John.

Bay de Chaleur (*Logan*); Sydney? (*R. Brown*).

8. S. LESQUEREUXII, Newberry.

M. C., Sydney (*R. Brown*).

9. S. MICROLOBA, Guttbier.

M. C., Sydney (*R. Brown*).

10. S. OBTUSILOBA (?), Brongn.

M. C., Bay de Chaleur (*Logan*).

PHYLLOPTERIS, Brongn.

PHYLLOPTERIS ANTIQUA, spec. nov. Pl. XIII. fig. 96

Pinnate; petiole thick, woody; pinnules oblong, pointed, attached by the middle of the base; midrib strong, extending to the point, giving off very oblique nerves, which have obliquely pinnate nervules not anastomosing. A remarkable frond, which, if not the type of a new genus, must belong to that above named.

M. C., Sydney (*R. Brown*).

ALETHOPTERIS, Sternberg.

1. ALETHOPTERIS LONCHITICA, Sternberg.

M. and U. C., Joggins (*J. W. D.*); M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

Very abundant throughout the Middle and Upper Coal-formations, and so variable that several species might easily be founded on detached specimens.

2. A. HETEROPHYLLA, L. & H.

L. C., Parrsborough (*A. Gesner*).

3. A. GRANDINI, Brongn.

M. C., Sydney (*R. Brown*).

4. A. NERVOSA, Brongn.

M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*); U. C., Pictou (*J. W. D.*).

5. A. MURICATA, Brongn.

M. C., Joggins, Bathurst (*Lyell*); U. C., Pictou (*J. W. D.*).

6. A. PTEROIDES, Brongn. (*A. Brongnartii*, Goeppert).

L. or M. C., Bathurst (*Lyell's list*).

7. A. SERLII, Brongn.

M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*).

8. A. GRANDIS, spec. nov. Pl. XIII. fig. 100.

Bipinnate; pinnæ broad, contiguous, united at the base; veins numerous, once forked, not quite at right angles to the midrib. Upper pinnæ having the pinnules confluent so as to give crenate edges. Still higher the apex of the frond shows distant decurrent long pinnules with waved margins. A very large and fine species of the type of *A. Serlii* and *A. Grandini*, but much larger and different in details. Its texture seems to have been membranaceous; and fragments from that part of the frond where the long simple pinnules are passing into the compound ones might be mistaken for an *Odontopteris*.

Bay de Chaleur (*Logan*).

PECOPTERIS, Brongn.

1. PECOPTERIS ARBORESCENS, Schloth.

Seems to have been an herbaceous species with a very strong petiole. It occurs in an erect position in a sandstone on Wallace River.

M. C., Sydney (*R. Brown*); U. C., Picton (*J. W. D.*); Wallace River (*Dr. Creed*).

2. P. ABBREVIATA, Brongn.

M. C., Sydney (*R. Brown*); Salmon River, U. C., Pictou (*J. W. D.*). Very common both in the Upper and Middle Coal-formations.

3. P. RIGIDA, spec. nov.

Similar to *P. arborescens*, but much smaller, and with finer nerves. U. C., Pictou (*J. W. D.*).

4. P. UNITA, Brongn.

Certain pinnules of a frond are sometimes swollen as if covered with fructification below; and in this state they resemble *P. arguta*, Brongn. The sori are seen in other specimens, and are large, round, and covered with an indusium as in *Aspidium*.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

5. P. PLUMOSA, Brongn.

M. C., Sydney (*R. Brown*).

6. P. POLYMORPHA, Brongn.

M. C., Sydney (*R. Brown*).

7. P. ACUTA, Brongn.

M. C., Pictou (*J. W. D.*).

8. P. LONGIFOLIA, Brongn.

In Bunbury's list, from Sydney.

9. P. TÆNIOPTEROIDES, Bunbury.

M. C., Sydney (*R. Brown*).

10. P. CYATHEA, Brongn.

M. C., Sydney (*R. Brown*).

11. P. ÆQUALIS, Brongn.

M. C., Sydney (*R. Brown*).

12. P. SILLIMANI?, Brongn.

In Lyell's list, from Sydney.

13. P. VILLOSA, Brongn.

M. C., Pictou (*Lyell's list*).

14. P. BUCKLANDI, Brongn.

M. C., Sydney (*Brown's list*).

15. P. OREOPTEROIDES, Brongn.

M. C., Sydney (*Brown's list*).

16. P. DECURRENS, Lesq.

Has pinnules more crowded, decreasing towards the apex, but may be a variety.

M. C., Sydney (*R. Brown*).

17. P. PLUCKENETII, Sternb.

M. C., Sydney (*R. Brown*).

BEINERTIA, Goeppert.

BEINERTIA GŒPPERTI, spec. nov. Pl. XIII. fig. 101.

Bipinnate; pinnæ broad, contiguous, obtuse, with thick pinnules. Pinnules rounded above, obovate below. Midrib thick, oblique, dividing above into a tuft of irregular hair-like veins.

M. C., Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); U. C., Joggins (*J. W. D.*).

HYMENOPHYLLITES, Goeppert.

HYMENOPHYLLITES PENTADACTYLA, spec. nov.

In general habit like *Sphenopteris microloba*, Goepp., but with pinnules divided into from four to seven obtuse cuneate lobes, each with one vein.

M. C., Sydney (*R. Brown*).

PALÆOPTERIS, Geinitz.

1. PALÆOPTERIS HARTII, spec. nov. Pl. VIII. fig. 35.

Stem or leaf-bases transversely wrinkled with delicate lines: scars transversely oval, slightly appendaged below; vascular scars confluent. Breadth 1·4 in.; length 0·6 in.

M. C., Grand Lake (*C. F. Hartt*).

2. P. ACADICA, spec. nov. Pl. VIII. fig. 36.

Stem or leaf-bases longitudinally striated: scars transverse, flat above, rounded and bluntly appendaged below: vascular scars in a transverse row. Breadth of scars 0·7 inch: length 0·5 inch.

U. C., Pictou (*J. W. D.*).

CAULOPTERIS, L. & H.

Several small erect stems at the Joggins seem to be trunks of ferns, but are too obscure for description.

PSARONIUS, Cotta.

Trunks of this kind must be rare in the Nova Scotian coal-fields A few obscure stems surrounded by cord-like aërial roots have been found, and probably are remains of plants of this genus.

MEGAPHYTON, Artis.

1. MEGAPHYTON MAGNIFICUM, spec. nov. Pl. VIII. fig. 34.

Stems large, roughly striated longitudinally; scars contiguous, orbicular, deeply sunk, nearly 3 inches in diameter, and each with a bilobate vascular impression 2 inches broad and an inch high.

M. C., Joggins (*J. W. D.*).

2. M. HUMILE, spec. nov. Pl. VIII. fig. 33.

Stem 2·5 inches in diameter; leaf-scars prominent, flattened, and broken at the ends, 1 inch wide. Surface of the stem marked with irregular furrows, and invested with a carbonaceous coating. An internal axis, nearly 2 inches in diameter, with a coaly coating, sends off obliquely thick branches to the leaf-scars. This is a very remarkable specimen, and throws much light on the structure of *Megaphyton*. Unfortunately the minute structures are not preserved.

M. C., Sydney (*R. Brown*).

Genus LEPIDODENDRON, Sternberg.

1. LEPIDODENDRON CORRUGATUM, Dawson, Quart. Journ. Geol. Soc. vol. xv. Pl. XI. fig. 53.

Areoles elongate ovate, acute at both ends, with a ridge along the middle, terminating in a single elevated vascular scar at the upper end. In certain states the vascular mark appears in the middle of the areole. In young branches the areoles are contiguous and resemble those of *L. elegans*. In old stems they become separated by spaces of longitudinally wrinkled bark; in very old stems these spaces are much wider than the areoles. Leaves linear, 1 inch or more in length, usually reflected, one-nerved. Cones (*Lepidostrobi*) terminal, short, cylindric, with numerous short, acute-triangular scales. Structure of stem:—a central pith with a slender cylinder of scalariform vessels, exterior to which is a thick cylinder of cellular tissue and bast fibres, and a dense outer bark.

Var. *verticillatum* has the areoles arranged in regular decussate whorls instead of spirally. This difference, which might at first sight seem to warrant even a generic distinction, is proved by specimens in my possession to be merely a variety of *phyllotaxis*.

This species is eminently characteristic of the Lower Carboniferous Coal-measures, and has not yet been found in the Middle Coal-formation. Fragments of bark resembling that of this species, occur in the Coal-formation of Bay de Chaleur, along with leafy branches of *Lepidodendron*, which resemble those of this species, though, I believe, distinct.

L. C., Horton, &c. (*C. F. Hartt; J. W. D.*); Norton Creek, &c., New Brunswick (*G. F. Matthew*).

2. L. PICTOENSE, spec. nov. Pl. IX. fig. 37.

Areoles contiguous, prominent, long oval, acuminate, separated in young stems by a narrow line; breadth to length as 1 to 3, or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch. Leaves contracted at the base, widening slightly, and gradually contracting to a point; ribs three, central distinct, lateral obscure; length 1 inch. Cones borne at the extremities of the smaller branches, oblong, obscurely scaly.

In habit of growth this species resembles *L. elegans*, for which imperfect specimens might be mistaken. It is also near to *L. binerve* and *L. patulum*, Bunbury*. It abounds in the Middle Coal-measures.

M. C., Sydney (*R. Brown*); Pictou (*H. Poole and J. W. D.*); Grand Lake (*C. F. Hartt*).

3. L. RIMOSUM, Sternberg.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

4. L. DICHOTOMUM, Sternberg (*L. Sternbergii*, L. & H.).

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*); L. C., Horton, (*J. W. D.*).

5. L. DECURTATUM, spec. nov. Pl. IX. fig. 40.

Areoles approximate or separated by a shallow furrow, rhombic ovate, obliquely acuminate below, nearly as broad as long, wrinkled transversely, especially on the middle line, which appears tuberculated; vascular scar rhombic, twice as broad as long, with three approximate vascular points. In some flattened specimens the line separating the areoles is indistinct, and the scars appear on a transversely wrinkled surface without distinct areoles.

M. C., Pictou (*J. W. D.*).

6. L. UNDULATUM, Sternberg. Pl. IX. fig. 41.

Possibly several species are included under this name; but they cannot be separated at present.

M. C., Sydney (*R. Brown*); Joggins and Pictou (*J. W. D.*); U. C., Joggins (*J. W. D.*).

7. L. DILATATUM, Lindley & Hutton.

M. C., Joggins (*J. W. D.*).

8. L., sp. like TETRAGONUM, Goepp.

Obscurely marked, but a distinct species, unless an imperfectly preserved variety of *L. tetragonum*. The areoles are square, with a rhombic scar at the upper corner of each.

L. C., Horton (*J. W. D.*).

9. L. BINERVE, Bunbury.

M. C., Sydney (*R. Brown*).

10. L. TUMIDUM, Bunbury.

I think it probable that this species belongs to the genus *Lepidophloios*; but I have not seen a specimen.

M. C., Sydney (*R. Brown*).

11. L. GRACILE, Brongn.

In Brown's list in 'Ac. Geology.' Probably a variety of the next.

M. C., Sydney (*R. Brown*).

12. L. ELEGANS, Brongn.

In Bunbury and Brown's lists.

M. C., Sydney (*R. Brown*).

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* In certain states of preservation, the lateral ribs of the leaves become obsolete; and in others the central disappears, in which state the resemblance to *L. binerve* is very close.

13. L. PLUMARIUM, L. & H.
M. C., Sydney (*in Brown's list*).

14. L. SELAGINOIDES, Sternb.
M. C., Sydney (*in Brown's list*).

15. L. HARCOURTII (Witham).
M. C., Sydney (*in Brown's list*).

16. L. CLYPEATUM (?), Lesqx.
M. C., Sydney (*R. Brown*); U. C., Joggins (*J. W. D.*).

17. L. ACULEATUM. Sternberg.
M. C., Sydney (*R. Brown*).

18. L. PLICATUM, spec. nov. Pl. IX. fig. 38.

Leaf-areoles much elongated; breadth to length as 1 to 5 or 6, transversely rugose: central line indistinct. Leaf-scar rhombic, with three vascular points; scars in old stems separated by rugose bark, and somewhat elongate.
M. C., Pictou (*J. W. D.*).

19. L. PERSONATUM, spec. nov. Pl. IX. fig. 39.

Areoles ovate acuminate; breadth to length as 1 to 3 or 4, contiguous in young stems; central lines distinct; lower part of areole with transverse lines. Leaf-scars ovate, with two marks above and two below; leaves slender, 1 inch long, one-nerved.
M. C., Sydney (*R. Brown*).

HALONIA, sp. HALONIA, L. & H.

A specimen probably referable to this genus from Grand Lake, in the collection of C. F. Hartt.

LEPIDOSTROBUS, Brongn.

1. LEPIDOSTROBUS VARIABILIS, L. & H.
The most common species.
M. C., Sydney (*R. Brown*); Pictou and Joggins (*J. W. D.*).

2. L. SQUAMOSUS, spec. nov. Pl. 10. fig. 46.

2 to 3 inches long, 1 inch thick; scales large, broadly trigonal, acute. Allied to *L. trigonolepis*, but larger. Probably a cone of *Lepidophloios*.
M. C., Grand Lake (*C. F. Hartt*).

3. L. LONGIFOLIUS, spec. nov.
Long-leaved, like *Lepidodendron longifolium*, L. & H.
M. C., Joggins (*J. W. D.*).

4. LEPIDOSTROBUS, sp.
Acute trigonal leaves, small.
M. C., Joggins (*J. W. D.*).

5. LEPIDOSTROBUS, sp.
Round, with obscure scales and remains of long leaves.
L. C., Horton (*J. W. D.*).

6. L. TRIGONOLEPIS, Bunbury.
M. C., Sydney (*R. Brown*).

LEPIDOPHYLLUM, Brongn.

1. LEPIDOPHYLLUM LANCEOLATUM, L. & H.
M. C., Joggins; U. C., Pictou (*J. W. D.*).

2. L. TRINERVE (?), L. & H.
Two-nerved or three-nerved, like *L. trinerve*, L. & H., but narrower. Both the above are parts of *Lepidostrobi*.
U. C., Joggins (*J. W. D.*).

3. L. MAJUS (?), Brongn.
M. C., Sydney (*R. Brown*).

4. LEPIDOPHYLLUM, sp.
Broad ovate, short, pointed, one-nerved, half an inch long.
U. C., Pictou.

5. L. INTERMEDIUM, L. & H.
M. C., Sydney (*R. Brown's list*).

Halonia, *Lepidostrobus* and *Lepidophyllum*, including only parts of *Lepidodendron* and *Lepidophloios*, are to be regarded as merely provisional genera.

LEPIDOPHLOIOS, Sternberg.

1. LEPIDOPHLOIOS ACADIANUS, spec. nov. Pl. X. fig. 45, Pl. XI. fig. 51.

Leaf-bases broadly rhombic, or in old stems regularly rhombic, prominent, ascending, terminated by very broad rhombic scars having a central point and two lateral obscure points. Outer bark laminated or scaly. Surface of inner bark with single points or depressions. Leaves long, linear, with a strong keel on one side, 5 inches or more in length. Cone-scars sparsely scattered on thick branches, either in two rows or spirally, both modes being sometimes seen on the same branch. Scalariform axis scarcely an inch in diameter in a stem 5 inches thick. Fruit, an ovate strobile with numerous acute scales covering small globular spore-cases. This species is closely allied to *Ulodendron majus* and *Lepidophloios laricinus*, and presents numerous varieties of marking.

M. C., Joggins, Salmon River, Pictou (*J. W. D.*); Sydney (*R. Brown*).

2. L. PROMINULUS, spec. nov. Pl. XI. fig. 52.

Leaf-bases rhombic pyramidal, somewhat wrinkled at the sides, truncated by regularly rhombic scars, each with three approximate vascular points.

M. C., Joggins (*J. W. D.*).

3. L. PARVUS, spec. nov. Pl. XI. fig. 50.

Leaf-bases rhombic, small, with rhombic scars broader than long;

vascular points obscure; leaves linear, acute, 3 inches or more in length, with a keel and two faint lateral ribs. Cones large, sessile.

U. C., Pictou; M. C., Joggins (*J. W. D.*); M. C., Sydney (*R. Brown*).

4. L. PLATYSTIGMA, spec. nov. Pl. X. figs. 47 & 48.

Leaf-bases rhombic, broader than long, little prominent; scars rhombic, oval, acuminate, slightly emarginate above; vascular points two, approximate or confluent.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

5. L. TETRAGONUS, spec. nov. Pl. X. fig. 49.

Leaf-bases square, furrowed on the sides; leaf-scar central, with apparently a single central vascular point.

M. C., Joggins (*J. W. D.*).

DIPLOTEGIUM, Corda.

DIPLOTEGIUM RETUSUM, spec. nov. Pl. XIII. fig. 102.

The fragments referable to plants of this genus are imperfect and obscure. The most distinct show leaf-bases ascending obliquely, and terminating by a retuse end with a papilla in the notch. Some less distinct fragments may possibly be imperfectly preserved specimens of *Lepidodendron* or *Lepidophloios*.

M. C., Joggins (*J. W. D.*).

KNORRIA.

Nearly all the plants referred to this genus in the Carboniferous rocks are, as Goeppert has shown, imperfectly preserved stems of *Lepidodendron*. In the Lower Coal-formation many such *Knorria* forms are afforded by *L. corrugatum*.

KNORRIA SELLONII, Sternberg.

This appears different from the ordinary *Knorriæ*; its supposed leaves may be aërial roots. It has a large pith-cylinder with very distant tabular floors, like *Sternbergia*.

M. C., Sydney (*R. Brown*).

CORDAITES, Unger. (PYCHNOPHYLLUM, Brongn.)

1. CORDAITES BORASSIFOLIA, Corda.

M. C., Pictou (*H. Poole*); Grand Lake (*C. F. Hartt*); Sydney (*R. Brown*); Joggins, Onslow (*J. W. D.*); Bay de Chaleur (*Logan*).

Very abundant in the Middle Coal-formation.

2. C. SIMPLEX, spec. nov.

Leaves similar to the last in size and form, but with simple, equal, parallel nerves. It may be a variety, but is characteristic of the Upper Coal-formation.

M. C., Grand River (*C. F. Hartt*); U. C., Pictou (*J. W. D.*).

CARDIOCARPUM, Brongn.

1. CARDIOCARPUM FLUITANS, spec. nov. Pl. XII. fig. 74.

Oval; apex entire or notched; surface slightly rugose; nucleus round ovate, acuminate, pitted on the surface, with a raised mesial line.
M. C., Joggins (*J. W. D.*).

2. C. BISECTUM, spec. nov. Pl. XII. fig. 73.

Nucleus as in the last species, but striate; margin widely notched at apex, and more narrowly notched below.
M. C., Grand Lake (*C. F. Hartt*).

3. CARDIOCARPUM, sp. like *C. marginatum*.

M. C., Joggins (*J. W. D.*).

4. CARDIOCARPUM, sp. allied to *C. latum*, Newberry.

M. C., Pictou (*H. Poole*).

These *Cardiocarpa* are excessively abundant in the roofs of some coal-seams; and the typical ones must have been samaras or winged nutlets. They must have belonged to phænogamous plants, and certainly are not the fruits of *Lepidodendron*, though some of the spore-cases of this genus have been described as *Cardiocarpa*. These I propose to place under the provisional genus *Sporangites*.

SPORANGITES, Dawson.

1. SPORANGITES PAPILLATA, spec. nov. Pl. XII. fig. 80.

I propose the provisional generic name of *Sporangites* for spores or spore-cases of *Lepidodendron*, *Calamites*, and similar plants, not referred to the species to which they belong. The present species is round, about 1 inch in diameter, and covered with minute raised papillæ or spines. It abounds in the roof of several of the shaly coals in the Joggins section, and especially in one in group 19 of that section.
M. C., Joggins (*J. W. D.*).

2. S. GLABRA, spec. nov. Pl. XII. fig. 81.

About the size of a mustard-seed, round and smooth. Exceedingly abundant in the Lower Carboniferous Coal-measures of Horton Bluff, with *Lepidodendron corrugatum*, to which it possibly belongs. A similar spore-case, possibly of another species of *Lepidodendron*, occurs rarely in the Middle Coal-formation at the Joggins.

STERNBERGIA, Artis.

This provisional genus includes the piths of *Dadoxylon*, *Sigillaria*, and other plants, usually preserved as casts in sandstone, retaining more or less perfectly the transverse partitions into which the pith-cylinders of many coal-formation trees became divided in the process of growth. These fossils are most abundant in the Upper Coal-formation, but occur also in the Middle Coal-formation. The following varieties may be distinguished:—

(*a*) Var. *approximata*, with fine uniform transverse wrinkles. This is usually invested with a thin coating of structureless coal.

(*b*) Var. *angularis*, with coarser and more angular transverse wrinkles. This is the character of the pith of *Dadoxylon*.

(*c*) Var. *distans*, usually of small size, and with distant and irregular wrinkles. This is sometimes invested with wood having the structure of *Calamodendron*, and perhaps is not generically distinct from *C. approximatum*.

(*d*) Var. *obscura*, with distinct and distant transverse wrinkles, but not strongly marked on the surface. This is the character of the pith-cylinders of *Sigillaria* and *Lepidophloios*.

ENDOGENITES, L. & H.

Many sandstone-casts, answering to the character of the plants described under this name by Lindley, occur in the Upper Coal-formation. They are sometimes 3 inches in diameter, and several feet in length, irregularly striated longitudinally, and invested with coaly matter. Sometimes they show transverse striation in parts of their length. I believe they are casts of pith-cylinders of the nature of *Sternbergia*, and probably of Sigillarioid trees.

SOLENITES, L. & H.

Plants of this kind are found in the sandstones of the Upper Coal-formation of the Joggins.

For all the specimens noticed in the above list as collected by Sir W. E. Logan, Richard Brown, Esq., of Sydney, Cape Breton, Henry Poole, Esq., of Glace Bay, C.B., and G. F. and C. B. Matthew and C. F. Hartt, Esqs., St. John, New Brunswick, I am indebted to the kindness of those gentlemen. To Mr. Brown especially I am under great obligations for his liberality in placing at my disposal his large and valuable collection of the plants of the Cape Breton coal-field.

EXPLANATION OF PLATES V.-XIII.

Illustrative of the Coal-plants of British North America.

PLATE V.

Fig. 1. *Dadoxylon antiquius*: longitudinal section, radial, magnified 90 diameters.
2. The same: longitudinal section, tangential, magnified 90 diameters: *a*, medullary rays.
3. The same: portions of cells showing areolation, magnified 250 diameters.
4. *Dadoxylon Acadianum*: longitudinal section, radial, magnified 90 diameters.
5. The same: longitudinal section, tangential, magnified 90 diameters: *a*, medullary rays.
6. The same: portion of cell showing areolations, magnified 250 diameters.
7. *Dadoxylon materiarium*: longitudinal section, radial, magnified 70 diameters.
8. The same: longitudinal section, tangential, magnified 70 diameters: *a*, medullary rays.
9. The same: portion of shell showing areolation, magnified 250 diameters.
10. *D. annulatum*: longitudinal section, radial, magnified 70 diameters.

Fig. 11. The same: longitudinal section, magnified 90 diameters: *a*, one of the concentric rings of compact coaly matter.
12. The same: portion of a cell showing areolation, natural size.
13. The same: transverse section, natural size: *a*, pith; *b*, wood, composed of alternate circles of areolated cells and compact coaly matter; *c*, coaly bark.

Plate VI.

Fig. 14. *Araucarites gracilis*: branch with leaves, three-fourths the natural size.
15. *Sigillaria Brownii*: portion of two ribs, 4 feet above the level, one-half the natural size: *a*, cortical; *b*, decorticated.
16. The same: portion of one rib near the root, furrowed and with vascular scars widely separated.
17. The same: trunk 1 foot in diameter at the base, showing the origin of the ribs.
18. The same: photograph of a portion of the upper part of the stem, one-half the natural size.
19. The same: portion of the base of the stem, one-half the natural size, from a photograph.
20. The same: Sigillarian root of this or an allied species.
21. *Sigillaria planicosta*, from a photograph, one-half the natural size; 21 *a*, scar and part of rib, one-half the natural size.
22. —— *catenoides*, from a photograph, one-half the natural size; 22 *a*, scar and part of ribs, one-half the natural size.
23. —— *striata*: flattened stem, from a photograph, two-thirds the natural size; 23 *a*, part of stem, same size; 23 *b*, scar, enlarged.
24. —— *eminens*: decorticated stem, from a photograph, much reduced; 24 *a*, scar, one-half the natural size.
25. —— *scutellata*, from a photograph, two-thirds the natural size, with band of interrupted growth; 25 *a*, ordinary areole, natural size; 25 *b*, areoles from the regular band, natural size.

Plate VII.

Fig. 26. *Sigillaria elegans*: decorticated stem, from a photograph, one-half the natural size, with band of interrupted growth at β; 26 *a*, corticated and flattened stem, one-half the natural size, with branches at β & γ; 26 *b*, leaf of *S. elegans*; 26 *c*, areoles of a branch; 26 *d*, areole of main stem.
27. —— *Bretonensis*: corticated stem, from a photograph, two-thirds the natural size; 27 *a*, areole, natural size.
28. —— *Sydnensis*: decorticated stem, from a photograph, two-thirds the natural size; 28 *a*, areoles of decorticated stem; 28 *b* & *c*, variety of Stigmarian root attached to this species.
29. *Antholithes squamosus*, from a photograph, two-thirds the natural size.
30. —— *Rhabdocarpi*, from a photograph, two-thirds the natural size; 30 *a*, a larger specimen of the same; 30 *b*, single nutlet of the same, natural size.
30 *c*. —— *pygmæus*: fragment, natural size.
31. *Calamodendron approximatum*, one-half the natural size; 31 *a*, cast of pith; 31 *b*, coaly or woody investment; 31 *c*, tissues of wood of *Calamodendron*, magnified.
31 *d*. Tissues of a different species of *Calamodendron* or of *Calamites*.

Plate VIII.

Fig. 32. Leaflets of *Cyclopteris Acadica*, from a photograph, one-third the natural size; 32 *a*, petiole of the same, one-third natural size; 32 *b*, divisions of petiole, one-half the natural size; 32 *c*, leaflets; 32 *d*, leaflet; 32 *e*, leaflet enlarged, showing venation; 32 *f*, striation of petiole enlarged; 32 *g*, *h*, remains of fructification; 32 *i*, base of petiole, much reduced.
33. *Megaphyton humile*: β, leaf-scars; γ, part of axis: from a photograph, two-thirds the natural size.

Fig. 34. *Megaphyton magnificum*: portion of stem, one-sixth the natural size; 34 *a*, leaf-scar, from a photograph, two-thirds the natural size.
35. *Palæopteris Hartii*, one-half the natural size.
36. —— *Acadica*, one-half the natural size.

Plate IX.

Fig. 37. *Lepidodendron Pictoense*, branchlets and leaves, from a photograph, one-half the natural size (β. cone); 37 *a*, leafy branch; 37 *b*, branch with areoles; 37 *c*, larger branch; 37 *d*, old stem with deep furrows, and at β areoles, not enlarged; 37 *e*, leaves. Figs 37 *a* to 37 *e*, from photographs two-thirds the natural size. 37 *f*, areole enlarged; 37 *g*, leaf enlarged.
38. —— *plicatum*, portion of old stem; 38 *a*, areole of branch, these areoles being placed in contact on such young branches.
39. —— *personatum*, leafy branch; 39 *a*, larger stem with areoles; both from photographs, two-thirds the natural size; 39 *b*, areole, enlarged; 39 *c*, leaf, natural size.
40. —— *decurtatum*, from a photograph, two-thirds the natural size; 40 *a*, areole, enlarged.
41. —— *undulatum*, portion of old stem, showing enlarged areoles, furrows, and two cone-scars.
42, 43. Portions of old stems, probably of *L. rimosum* or allied species.

Plate X.

Fig. 44. Portions of old stems, probably of *Lepidodendron rimosum* or an allied species.
45. *Lepidophloios Acadianus*, stem with marks of cones, from a photograph, one-half the natural size; 45 *a*, portion of stem with areoles, from a photograph, two-thirds the natural size; 45 *b*, decorticated stem, natural size; 45 *c* & *d*, opposite sides of the same stem, reduced, to show the different arrangement of the cone-scars; 45 *e*, part of a leaf, natural size; 45 *f*, *g*, *h*, areoles from different parts of stem.
46. Strobile of *Lepidophloios*; 46 *a*, transverse section of a similar strobile; from photographs, two-thirds the natural size.
47 & 48. *Lepidophloios platystigma*, from a photograph, two-thirds the natural size; 47 *a* & 48 *a*, areole of the same, natural size.
49. —— *tetragonus*, from photograph, two-thirds the natural size; 49 *a*, areole, two-thirds the natural size.

Plate XI.

Fig. 50. *Lepidophloios parvus*, stem with areoles and scars of cones; 50 *a*, group of leaves: both from photographs, two-thirds the natural size; 50 *b*, areole, natural size.
51. Cross section of *Lepidophloios Acadianus*, showing the outer rind and woody axis, one-tenth the natural size; 51 *a*, scalariform vessels of axis, magnified; 51 *b*, transverse section of part of the axis, showing the vascular bundles which proceed to the leaves, and the different diameters of the outer and inner circles of vessels; 51 *c*, smaller portion of the axis, showing one bundle of vessels.
52. *Lepidophloios prominulus*, portion of cast, from a photograph, two-thirds the natural size; 52 *a*, areole, natural size.
53. *Lepidodendron corrugatum*, young branch with cone; 53 *a*, branch with leaves; 53 *c*, older branch with areoles beginning to separate; 53 *d*, variety with alternate areoles; 53 *e*, variety with areoles in vertical rows; 53 *f*, *g*, old trunks, with widely separated areoles; 53 *h*, photograph of branch; 53 *i*, Knorria, or decorticated state; 53 *k*, fragment, showing ramification; 53 *l*, bark with areoles in transverse rows; 53 *m*, spore-case, natural size and magnified; 53 *n* to *r*, areoles in various states; 53 *s*, leaf, enlarged.
54. Scalariform vessel of *Lepidodendron*.
55. " " *Stigmaria*.

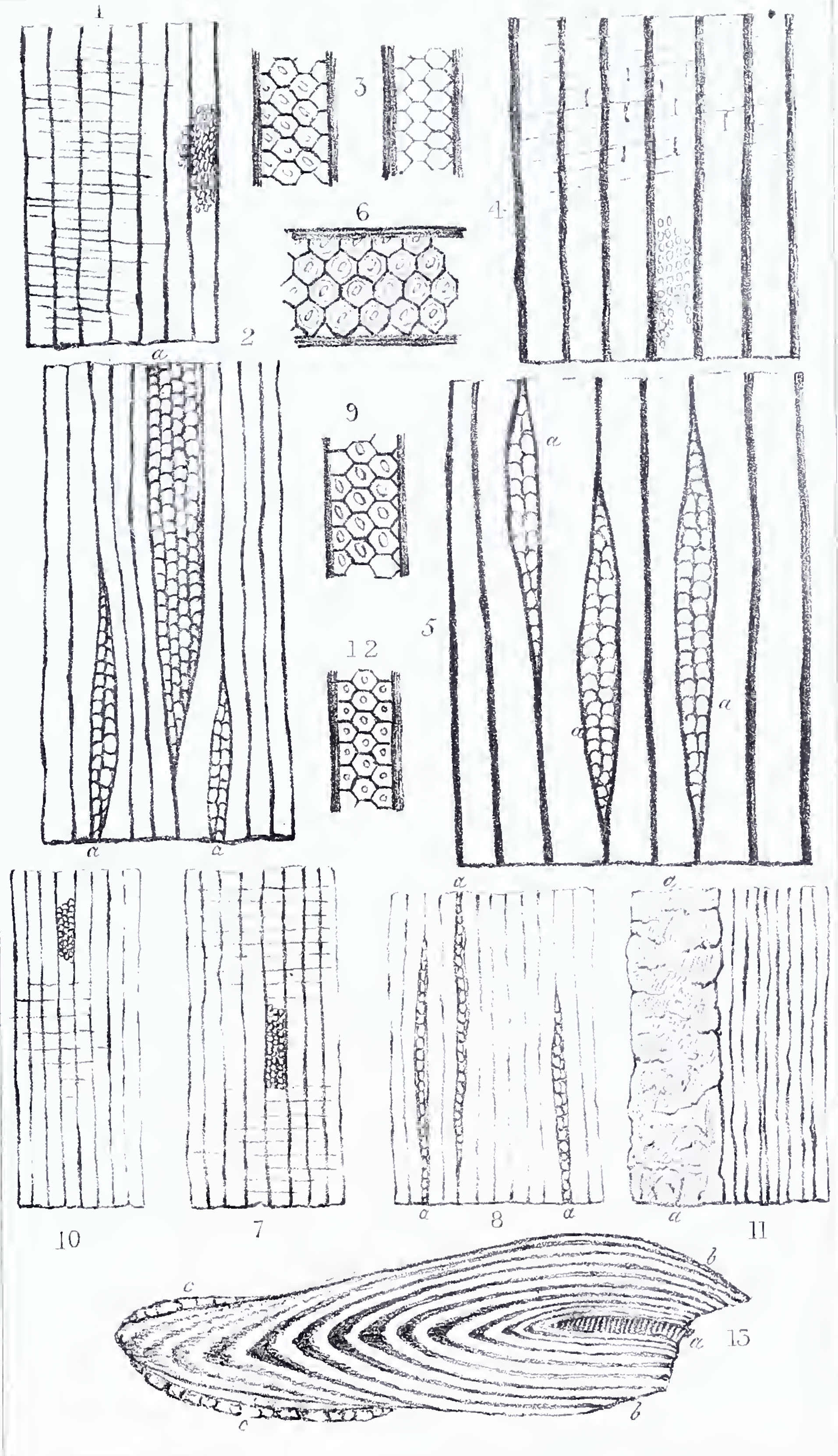
Plate XII.

Fig. 56. Scalariform vessel of *Lepidophloios*.
57. Tissues of *Sigillaria*.
58. Vessel of *Sphenophyllum*.
59. Tissues of *Calamodendron*.
60. Tissues of *Calamites*.
61. Scalariform tissue of Ferns.
62. Bast tissue of *Sigillaria*.
63. Cells of *Dadoxylon Acadianum*.
64. Cells of *D. materiarium*.
65. Cuticle of *Pinnularia*.
66. Vessel of *Sphenophyllum*, 200 diameters.
67. Vessels and cells from vascular bundles of Ferns, 200 diameters.
68. Tissues of *Sigillaria*, 200 diameters.
69. *Rhabdocarpus insignis*.
70–72. *Cardiocarpum*, spp.
73. *C. bisectum*.
74. *C. fluitans*.
75. *Trigonocarpum minus*.
76. *T. Sigillariæ*.
77. *T. avellanum*.
78. *T. intermedium*; 78 *a*, nucleus of do.
79. *T. Nœggerathi*.
80. *Sporangites papillata*; 80 *b*, nat. size.
81. *S. glabra*; 81 *b*, nat. size.
82. Fragment of *Antholithes*.
83. Stigmaria with scars in rhombic areoles.
84. Stigmaria with bark divided by vertical furrows (var. *alternans*).
85. Stigmaria with large scars in elongated areoles.
86. Stigmaria with elongated scars (*Knorria* form).
87. Stigmaria another variety, resembling *Diplotegium*.
88. *Equisetites curtus*.
89. *Calamites Nova-scoticus*.

Figs. 54–64 inclusive are drawn to a uniform scale of 90 diameters. Figs. 83 to 87 are taken from photographs, and are two-thirds the natural size.

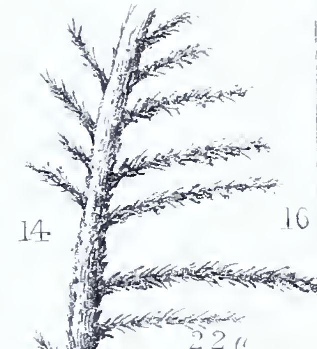
Plate XIII.

Fig. 90. *Asterophyllites trinervis*; 90 *a*, portion of leaf enlarged.
91. *Nœggerathia dispar*, one-half natural size.
92. *Cyclopteris hispida*; 92 *a*, portion of pinnule magnified, showing hairy surface and impressions of nervures.
93. *Neuropteris perelegans*; *a*, portion magnified, showing venation.
94. —— *cyclopteroides*.
95. *Cyclopteris antiqua*.
96. *Phyllopteris antiqua*; 96 *a*, portion magnified, showing venation.
97. *Sphenopteris munda*; 97 *a*, portion magnified.
98. —— *latior*; 98 *a*, pinnule magnified, showing venation and sori.
99. —— *Canadensis*; 99 *a*, pinnule magnified, showing venation.
100 and 100 *a* & *b*. Pinnules of *Alethopteris grandis*; 100 *a*, portion magnified, showing venation.
101. *Beinertia Goepperti*; 101 *a*, pinnule magnified, showing venation.
102. *Diplotegium retusum*; 102 *a*, leaf-scar magnified.
103. *Lonchopteris tenuis*; 103 *a*, portion enlarged, showing character of surface.



E.M. Williams. F.L.S. F.Z.S. lith.
M & N. Hanhart imp.

COAL-PLANTS OF BRITISH N. AMERICA.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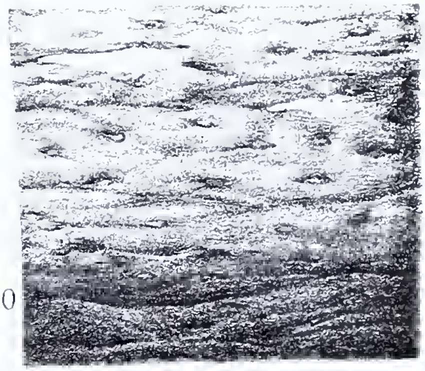
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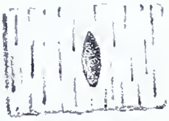
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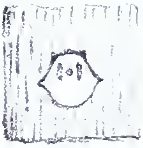
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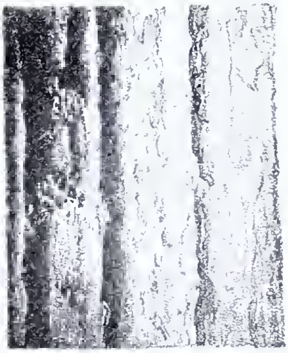
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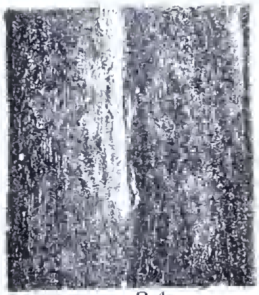
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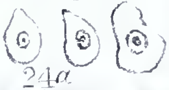
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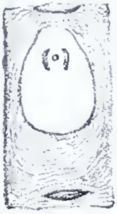
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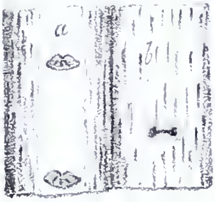

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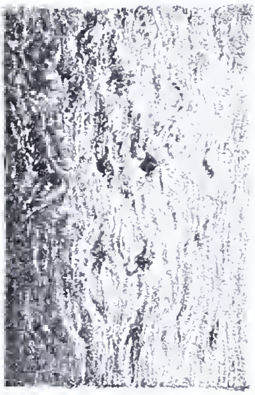
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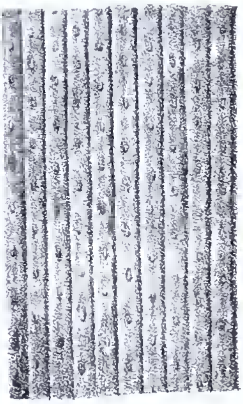
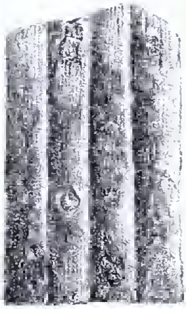
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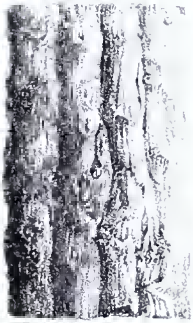
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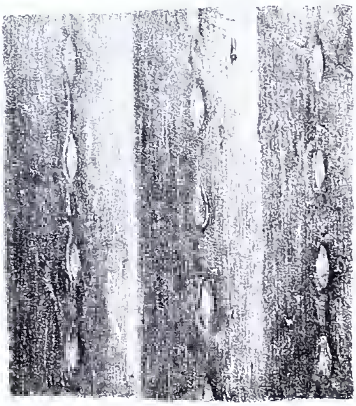
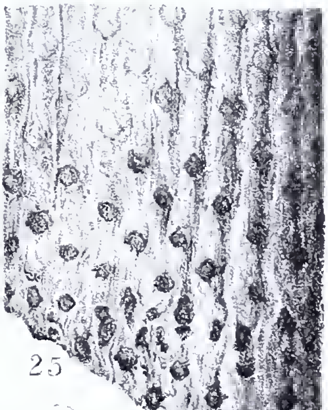
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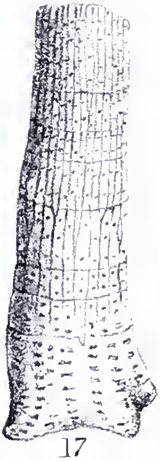
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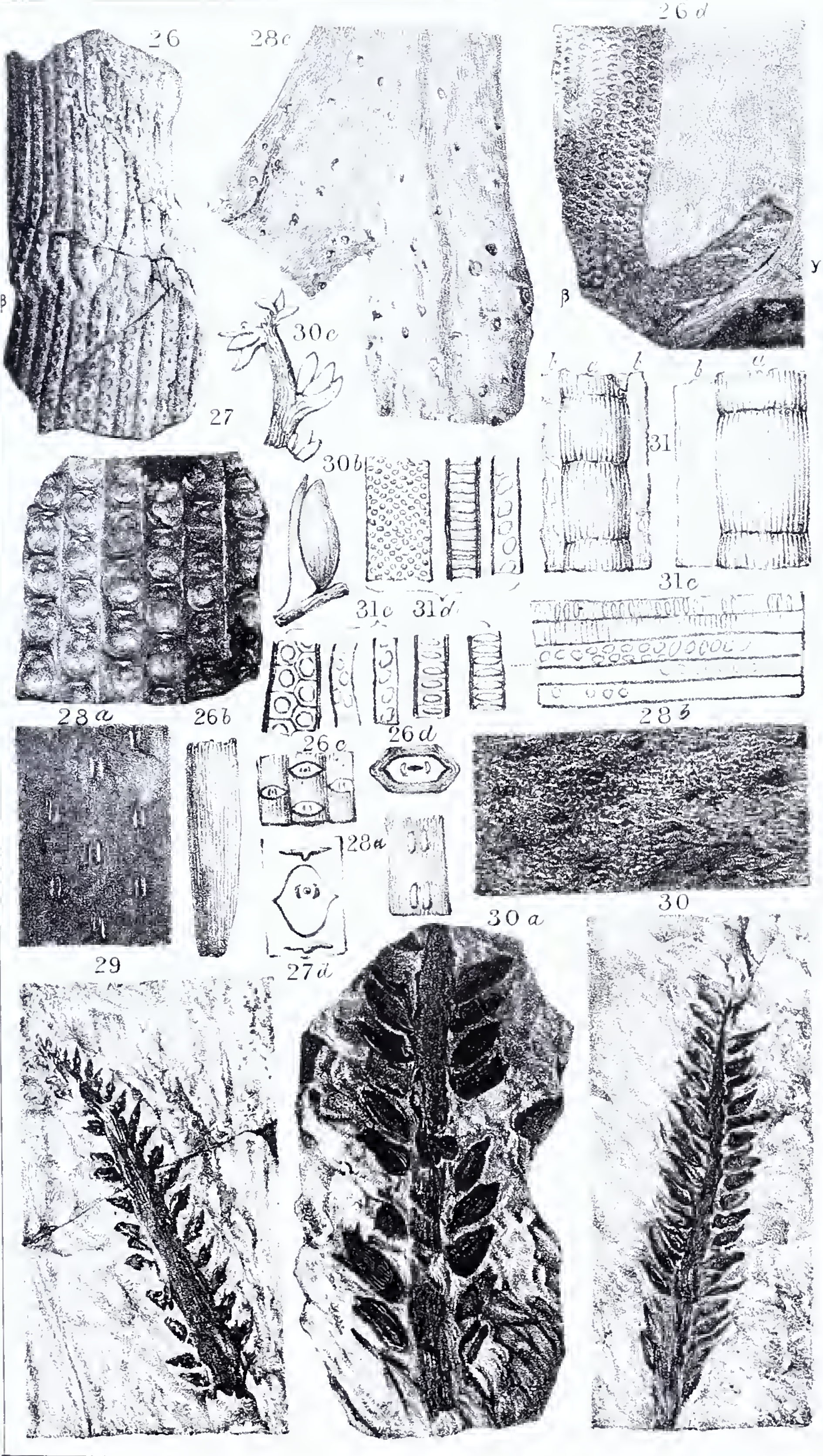
M & N Hanhart imp.

COAL-PLANTS OF BRITISH N. AMERICA



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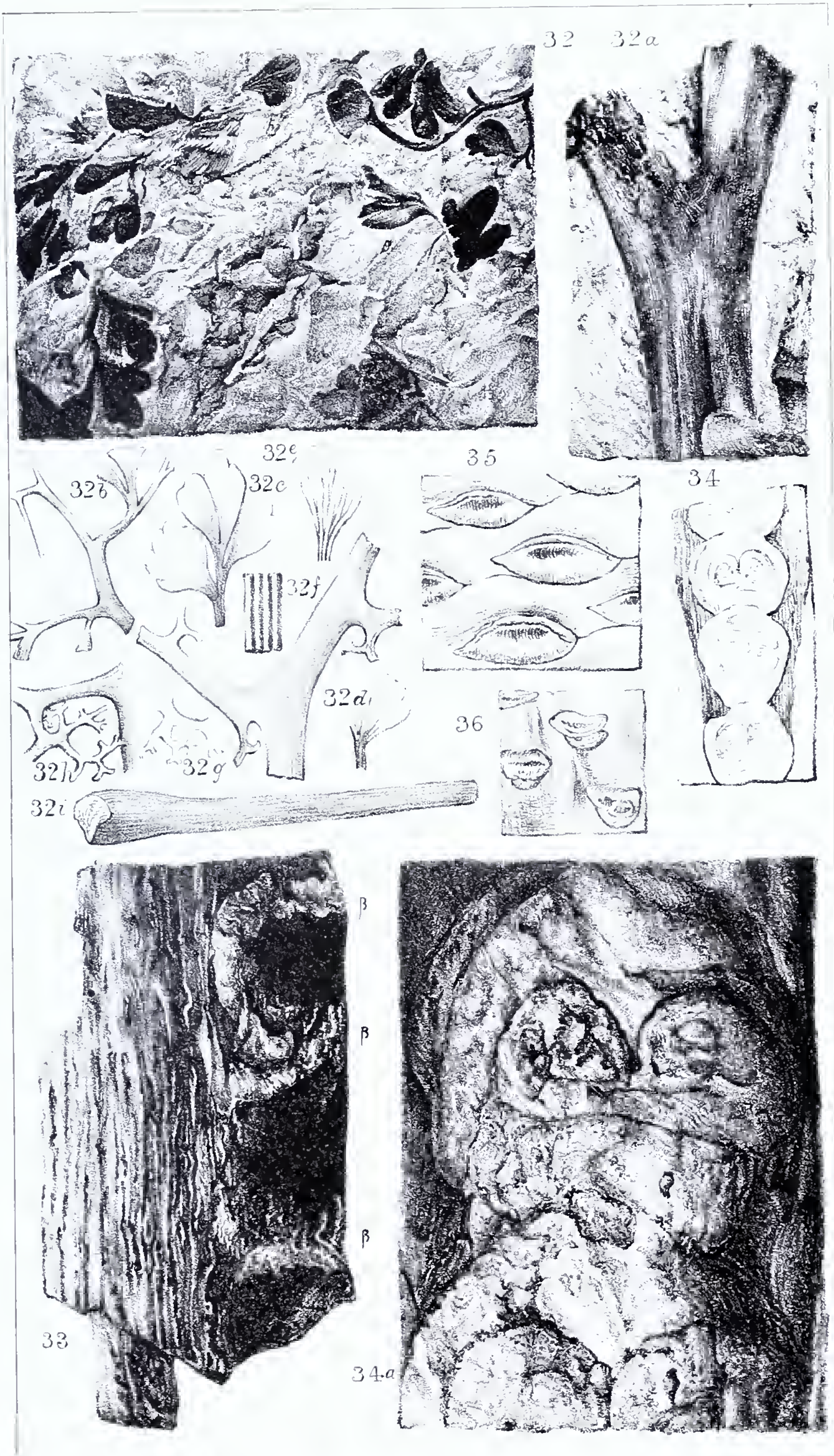

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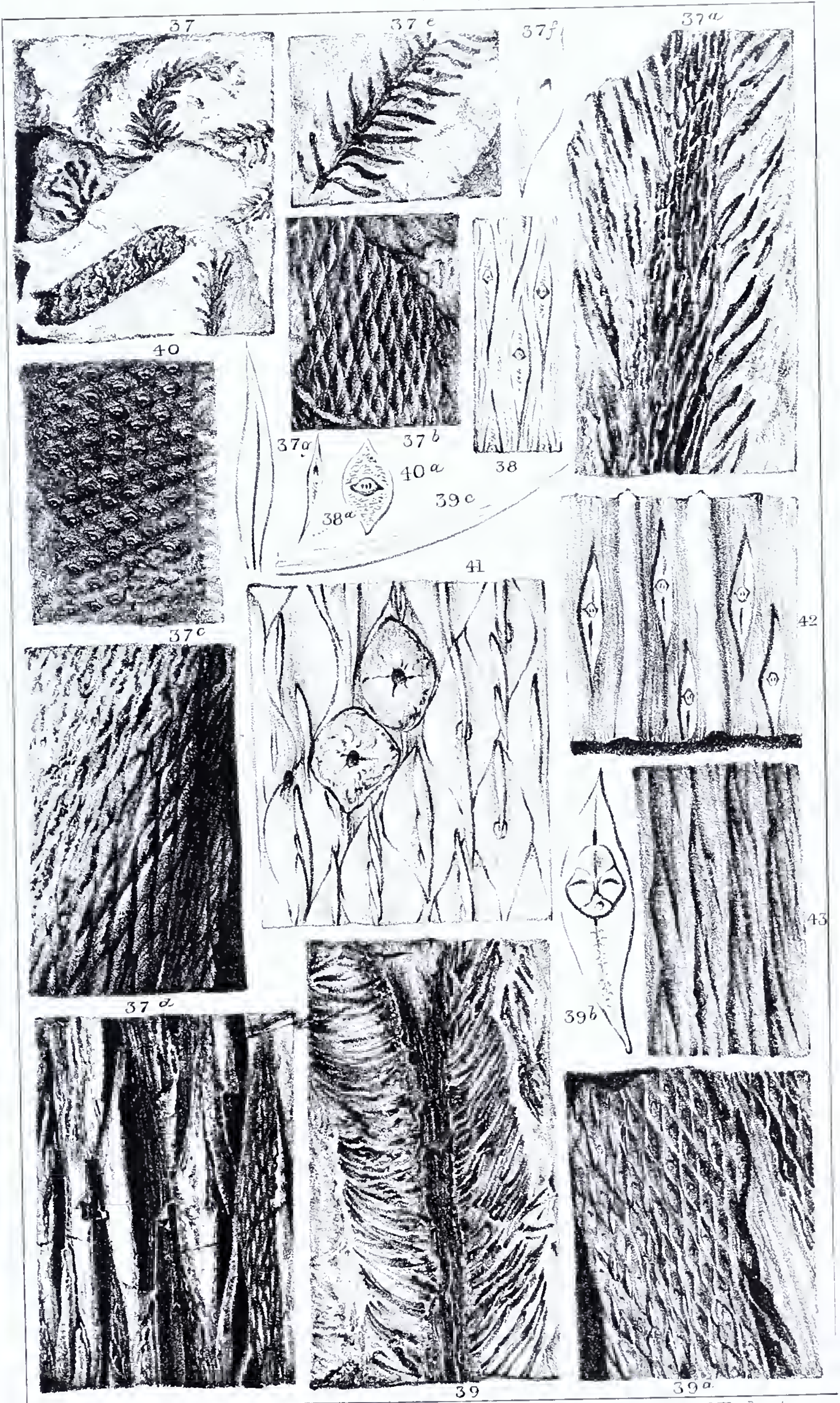

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COAL-PLANTS OF BRITISH N. AMERICA.

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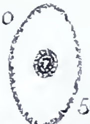

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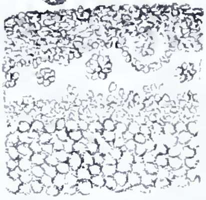

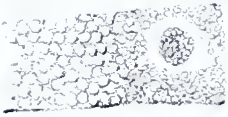

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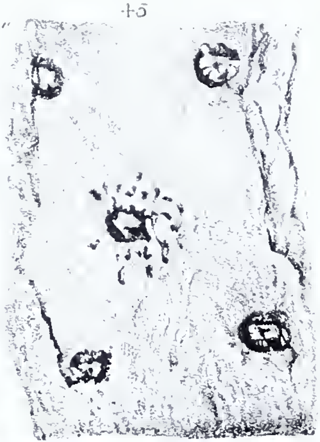

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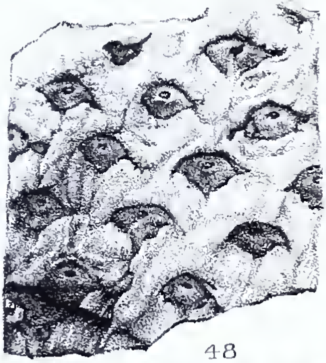

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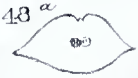

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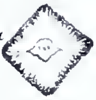

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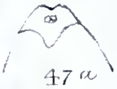

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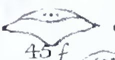

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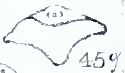

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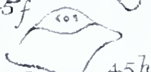

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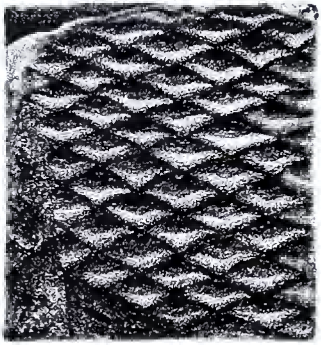

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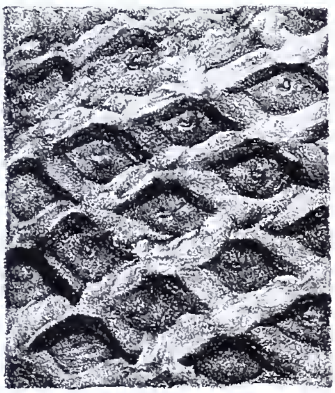

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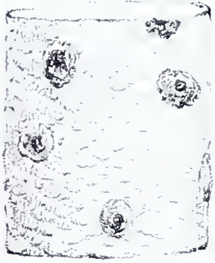

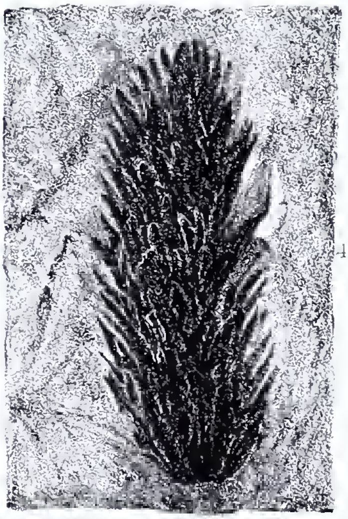

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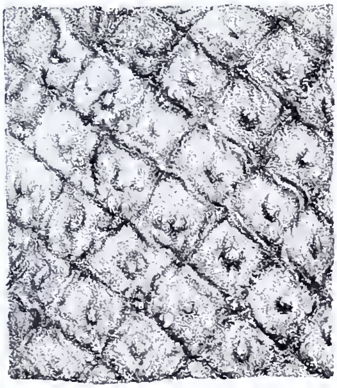

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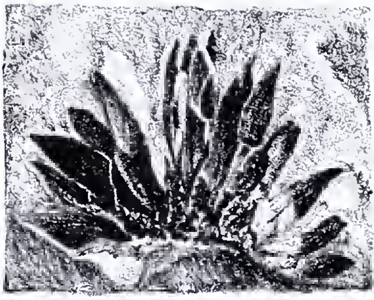

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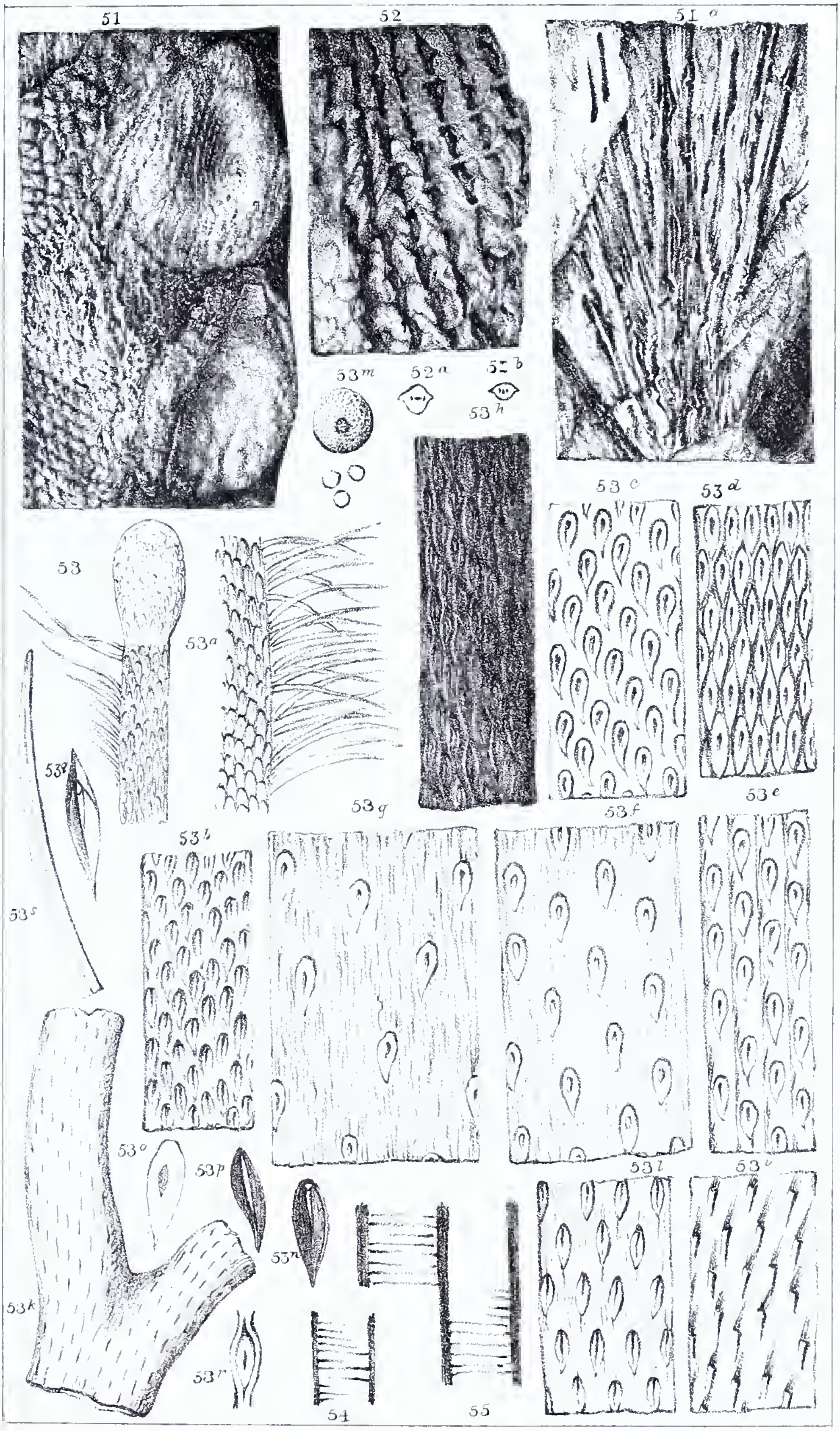
E.M. Williams F.L.S. F.Z.S. lith.

M. & N. Hanhart. imp.

COAL-PLANTS OF BRITISH N. AMERICA



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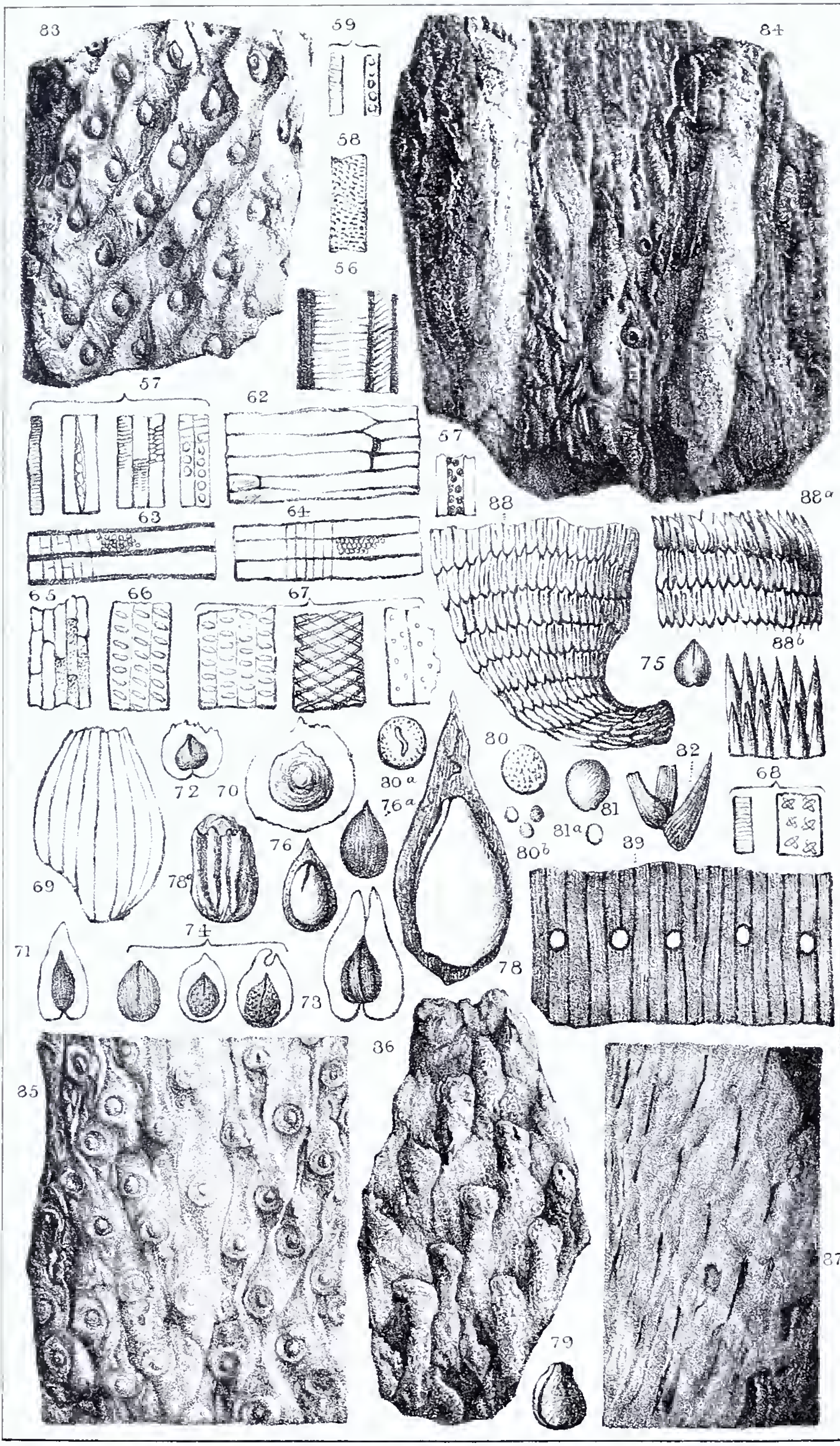
COAL-PLANTS OF BRITISH N. AMERICA



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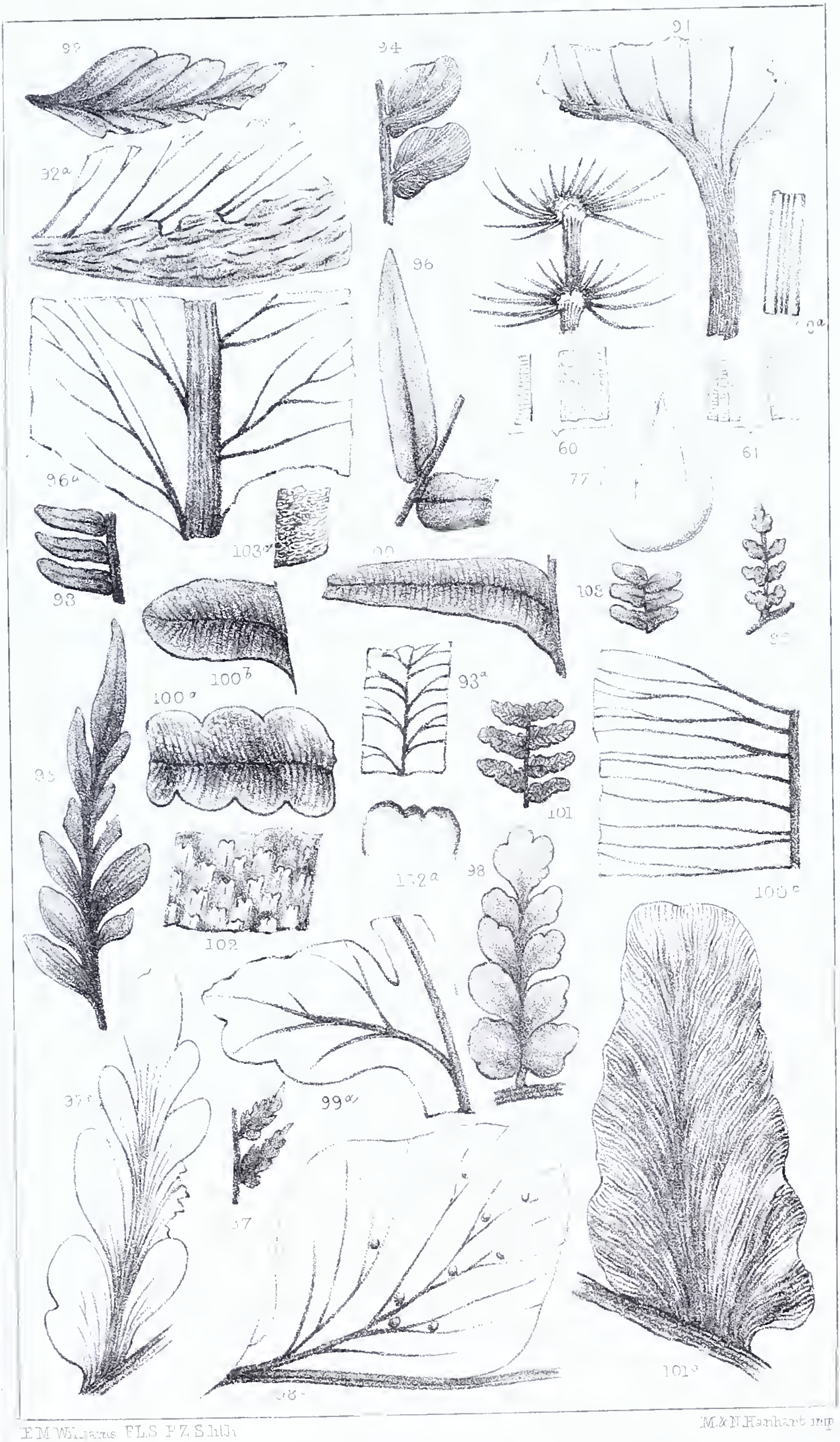

E.M. Williams F.L.S. F.Z.S. lith.

M.&N. Hanhart imp.

COAL-PLANTS OF BRITISH N. AMERICA.

[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for May* 1871.]

SURVEY OF PENNSYLVANIA

On the STRUCTURE *and* AFFINITIES *of* SIGILLARIA, CALAMITES *and* CALAMODENDRON.

By J. W. DAWSON, LL.D., F.R.S., F.G.S., Principal of McGill University.

(Read May 11, 1870 *.)

[Plates VII.-X.]

1. SIGILLARIA.

The difficulty of arriving at a correct knowledge of the structure of these curious trees is caused principally by the unequal durability of the different parts of the stem. It arises from this that some portions have usually perished, while others were in process of mineralization, and the portions which remain have in a great degree lost their original form and arrangement. The outer bark, while extremely durable, was too impenetrable to be preserved in any other way than as compact coal. The fibres of the bark and of the woody axis are often mineralized or imperfectly preserved as mineral charcoal. The cellular portions of the bark and of the axis have usually entirely disappeared. Still, imperfectly preserved stems can be obtained in great abundance in any coal-field by those who are content to work on such unpromising material.

Probably the finest specimen of a *Sigillaria* hitherto described is that of *S. elegans*, so admirably figured by Brongniart, and which has long served to give to the student of palæobotany his ideas of the structure of the genus. Unfortunately, however, Brongniart's specimen represents a small or young stem belonging to the somewhat aberrant subgenus *Favularia*; so that it fails to give an adequate idea of the structure of the typical fossil *Sigillariæ*, which are much more common and important, at least in the coal-fields of Nova Scotia. The structure of these last, as observed in specimens obtained at the South Joggins, was, I believe, first described by me in my paper on the Vegetable Structures in Coal, published in the 'Journal' of this Society in 1859. The specimens subsequently figured in the 'Journal' of this Society, and in the 'Transactions' of the Royal Society, by Mr. Binney, under the name of *S. vascularis*, belong, in part at least, to types of structure quite distinct from that of the true *Sigillariæ*†.

My own results as to the typical *Sigillariæ* are thus shortly summed up in my paper on the "Conditions of Deposition of Coal"‡:—"In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens; the pith is transversely partitioned in the manner of *Sternbergia*; and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in the coal, named 'bast-tissue.' The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk, when old, lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree."

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* For the discussion on this paper see Quart. Journ. Geol. Soc. vol. xxvi. p. 490.

† It would seem that the specimens figured by Mr. Binney as *Sigillaria vascularis* (Philos. Trans. vol. clv.) belong in part to the *axis* of a remarkable Sigillarioid tree, of which specimens have been kindly shown to me by Prof. Williamson, and in part (especially pl. xxxv. figs. 5 & 6) to the *whole stem* of a *Lepidodendron*. The latter plant has been described by Mr. Carruthers as *Lepidodendron selaginoides*.

‡ Quart. Journ. Geol. Soc. vol. xxii. p. 129.

It will be understood that this statement refers to the main stems of the ribbed *Sigillariæ* of the type of *S. reniformis* and *S. Brownii*, so abundant in the coal-formation of Nova Scotia, and that it is made with especial reference to the conditions of the accumulation of coal in that province. The evidence on which it is based may be stated under the following heads:—

Erect Trunks.—The numerous erect stumps of *Sigillariæ* occurring at the South Joggins, and at Sydney, Cape Breton, are usually preserved as casts in sandstone, the only part of their organic substance remaining being the outer bark, which exists in the state of compact coal. Still the interior structures have not altogether perished, but may be recognized as a layer of mineral charcoal in the bottom of the stony column, under the sand and other foreign matters subsequently introduced. Occasionally the bark of the tree has collapsed before it could be filled with sediment, and the only remains of the trunk consist of the little mound of carbonaceous matter derived from the tree itself. Cases of this kind are mentioned in my paper on the South Joggins*. In addition to the coaly matter showing structure, we can also occasionally find in the interior of such erect trees a transversely striated sandstone cast (*Sternbergia*) representing the medullary cylinder. In one instance only have I found the medullary cylinder calcified in such a manner as to show its structure, and surrounded by the woody cylinder also in a calcified state. This specimen was that described, but not adequately figured, in my paper on the Structures in Coal, and I now propose to figure it more in detail (Plate X.). Ordinarily the coaly mass consists of confused fragments of mineral charcoal derived from the wood and the fibrous tissues of the bark; but these often retain their structure very perfectly.

After collecting and examining the woody matter thus remaining in twenty or more of these erect trees, I have found that, with one exception, it consists of tissues of a uniform character, presenting only such differences as might be expected in trees generically allied. The tissues observed are discigerous or porous wood-cells with from one to four rows of pores, pseudo-scalariform tissue, and elongated structureless cells of the bark (the "bast-tissue" of my former papers). These structures indicate that the woody parts of these trees were identical in character with those of the calcified axis above mentioned.

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* Quart. Journ. Geol. Soc. vol. x. p. 1.

The exception above referred to is, that in one tree, which from its markings I supposed to be a *Sigillaria*, the woody tissue was composed of large cells, with many rows of pores ("multiporous tissue" of my former papers) of the type of that to which Prof. Williamson has given the name of *Dictyoxylon**. Since, however, as Prof. Williamson has well shown, such tissue may be regarded as a modification of the discigerous variety, and since Corda long ago found it in the axis of a species of *Stigmaria*†, there is nothing improbable in the supposition that we have here merely an indication of a specific or subgeneric difference coming within the limits of the genus *Sigillaria*, as at present understood.

It is to be observed that most of the erect trunks in the coal-formation have not preserved their external markings with sufficient distinctness to allow the species to be determined by the leaf-scars; but they show in most cases the characteristic ribs and rows of punctures or areoles, modified in the manner which is usual in the case of old trunks of these plants near their bases‡.

In Plate VIII. figs. 12, 14, 15, 16, I have represented some of the more usual forms of tissue in the erect *Sigillariæ*.

In Plate X. I have represented the best-preserved axis in my possession. Fig. 23 shows the structures in the entire stem, except the portions of cellular bark lost by decay. In the centre is a *Sternbergia*-pith (*a*). This is surrounded by a woody cylinder (*b*), the inner part of which (fig. 24, *b* 1) consists of scalariform tissue passing towards the outer surface into pseudo-scalariform (*b* 2), reticulated with pores (*b* 3), and discigerous (*b* 4). This woody axis has medullary rays (figs. 25, 26, 27), and is traversed by bundles of scalariform tissue proceeding from the inner part of the cylinder. The outer portion of the inner bark, not seen in this specimen, but in similar prostrate stems, is composed of elongated thin-walled bast-cells, with somewhat obtuse ends, and of larger diameter than the woody fibres of the axis (fig. 29). The tissues of the woody axis are all arranged in radial series (fig. 28).

Prostrate Trunks.—In the coarse shaly coals, and in the roof-shales of the ordinary seams, there are often flattened stems of *Sigillaria*, having the tissues partially infiltrated with carbonate of lime or carbonate and sulphate of iron. The tissues usually preserved in these flattened trunks are those of the bark, and more especially its large bundles of elongated or prosenchymatous cells ("bast-tissue"). Of this I have been enabled to obtain very perfect specimens from these flattened trunks. In a few instances only the woody structure of the axis remains, showing the same descriptions of wood-cells already referred to as characteristic of the erect trees. Plate VIII. fig. 11 is an example of the structures in one of these prostrate stems.

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* Trans. Royal Micro. Soc., Aug. 1869.

† Beiträge zur Flora &c. 1845, pl. xiii. Corda regards this as the structure of *S. ficoides*, and the more ordinary variety as that of *S. anabathra*.

‡ The species which I have described as *S. Brownii*, Acad. Geol. 2nd edition, may be regarded as a representative of these trees.

Sternbergiæ.—The fine specimen of the axis of an erect *Sigillaria* already referred to shows that the pith of these trees was of that transversely laminated character which gives rise to the fossils known as *Sternbergiæ*. Hence we may suppose that some at least of the numerous casts of *Sternbergiæ* found in the Coal-formation have been derived from *Sigillariæ*; but this can be ascertained only by a careful microscopic examination of the remains of woody matter clinging to the casts. The results of the study of a considerable number of specimens may be stated as follows:—

(*a*) As Prof. Williamson and the writer have shown, some of these *Sternbergia*-piths belong to coniferous trees of the genus *Dadoxylon*. Plate VII. fig. 1 represents a beautifully preserved cylinder of this kind enclosed in the wood of *Dadoxylon materiarum*.

(*b*) A few specimens present multiporous tissue, of the type of *Dictyoxylon*, which, according to Williamson, has a *Sternbergia*-pith. Plate VII. fig. 4 affords an instance of this.

(*c*) Other examples show a true scalariform tissue, comparable with that of *Lepidophloios* or *Lepidodendron*, but of finer texture. Corda has shown that plants of the type of the former genus (his *Lomatophloios*) had *Sternbergia*-piths. Some plants of this group are by external characters loosely reckoned by botanists as ribless *Sigillariæ* (*Clathraria*); but I believe that they are not related even ordinally to that genus. Plate VII. fig. 5 represents a *Sternbergia*, with tissue partly reticulated and partly scalariform. Plate VIII. fig. 7 represents a specimen with true scalariform tissue. Plate VII. fig. 6 is a scalariform vessel of *Lepidophloios* drawn to the same scale for comparison. It will be seen that it is of much coarser texture.

(*d*). The majority of carboniferous *Sternbergiæ* show structures identical with those described above as occurring in erect *Sigillariæ*. Such *Sternbergiæ* and their structures are represented in Plate VII. figs. 2 and 3, and Plate VIII. figs. 8, 9, 13. Fig. 8 is a reduced section of a large flattened tree, apparently a *Sigillaria* with *Sternbergia*-pith (fig. 9), of great beauty, and not dissimilar from those sometimes found in the erect *Sigillariæ*. The tissue enclosing it was unfortunately imperfectly preserved, but had three rows of pores (fig. 9 *a*).

Structures in Coal.—The constant association of *Sigillaria* with the beds of coal, in the underclays, in the roof-shales, and in the coal itself, is too well known to require any detailed reference; and the inevitable conclusion that the *Sigillariæ* were the principal plants concerned in the accumulation of the mineral fuel of the true coal-measures is generally accepted by geologists. It would naturally follow from this that tissues of *Sigillaria* should be more abundant in the coal than those of other plants. Accordingly, as I have shown in my paper on the "Structures in Coal," and on the "Conditions of Coal-deposition," tissues similar to those above described are those which actually occur most abundantly in the mineral charcoal of the coal-seams. That of the liber or fibrous bark is perhaps the most abundant of all, and that of the woody axis the next in frequency of occurrence.

It has been held to be an objection to the identification of the discigerous tissues above mentioned with those of *Sigillaria*, that the *Stigmariæ*, when their structure happens to be preserved, show merely scalariform tissue. To this it may be answered:—(1.) That, as Corda has shown*, some *Stigmariæ* have reticulated or multiporous tissues. (2.) The tissue of *Stigmaria* is not essentially different from the pseudo-scalariform fibres of the stem, and is arranged in a similar manner, showing that it is homologous rather with woody than with vascular tissue. (3.) Many *Stigmariæ* probably belong to *Favularia* and similar forms, or possibly even to Lepidodendroid plants†. In either case the structure would be unlike that of the stems of *Sigillaria* proper. (4.) Inasmuch as the proportions of pseudo-vascular and discigerous tissue may differ greatly in the stems of *Sigillariæ*, it would not be unreasonable to suppose that the tissue, which is more particularly important for the strengthening of the stem, should be absent, or in a feeble state of development, in the root. Something of this kind occurs in the roots of Cycads, and perhaps, if detailed examinations were made, might be found to be more general than is commonly supposed. (5.) The outer part of the axis, being left exposed by the decay of the loose cellular matter of the inner bark, may, in most cases, have perished. In my specimen of the axis of *Sigillaria*, above described, it is in parts much disorganized, and has disappeared, or been converted into coal, on one side.

The evidence included under the above heads is sufficient to show that the ordinary ribbed *Sigillariæ* referred to in my previous papers, possessed in their main trunks the following kinds of tissue, in proceeding from the circumference to the centre:—

(*a*) A dense cellular outer bark, usually in the state of compact coal—but when its structure is preserved, showing a tissue of thickened parenchymatous cells.

(*b*) A very thick inner bark, which has usually in great part perished, or been converted into coal, but which, in old trunks, contained a large quantity of prosenchymatous tissue, very tough and of great durability. This "bast-tissue" is comparable with that of the inner bark of modern Conifers, and constitutes much of the mineral charcoal of the coal-seams.

(*c*) An outer ligneous cylinder, composed of wood-cells, either with a single row of large bordered pores‡, in the manner of Pines and Cycads, or with two, three, or four rows of such pores sometimes inscribed in hexagonal areoles in the manner of *Dadoxylon*. This woody cylinder is traversed by medullary rays, which are short, and composed of few rows of cells superimposed. It is also traversed by oblique radiating bundles of pseudo-scalariform tissue proceeding to the leaves. In some *Sigillariæ* this outer cylinder was itself in part composed of pseudo-scalariform tissue, as in Brongniart's specimen of *S. elegans*; and in others its place may have been taken by multiporous tissue, as in a case above referred to; but I have no reason to believe that either of these variations occurred in the typical ribbed species now in question. The woody fibres of the outer cylinder may be distinguished most readily from those of Conifers, as already mentioned, by the thinness of their walls, and the more irregular distribution of the pores. Additional characters are furnished by the medullary rays and the radiating bundles of scalariform tissue when these can be observed.

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* Beiträge zur Flora der Vorwelt.

† Brown, in 1847, described, in the 'Proceedings' of this Society, Stigmaria-roots of *Lepidodendron*. Baily seems to have shown that such roots belong to the singular Lepidodendroid *Cyclostigma* of the Devonian of Ireland; and Schimper asserts a connexion of Stigmaria roots with trees which he refers to *Knorria*.

‡ These are the same with the wood-cells elsewhere called discigerous tissue, and to which I have applied the terms uniporous and multiporous. The markings on the walls are caused by an unlined portion of the cell-wall placed in a disk or depression, and this often surrounded by an hexagonal rim of thickened wall; but in all cases these structures are less pronounced than in *Dadoxylon*, and less regular in the walls of the same cell, as well as in different layers of the tissues of the axis.

(*d*) An inner cylinder of pseudo-scalariform tissue. I have adopted the term pseudo-scalariform for this tissue, from the conviction that it is not homologous with the scalariform ducts of Ferns and other Acrogens, but that is merely a modification of the discigerous wood-cells, with pores elongated transversely, and sometimes separated by thickened bars, corresponding to the hexagonal areolation of the ordinary wood-cells. A similar tissue exists in Cycads, and is a substitute for the spiral vessels existing in ordinary Exogens.

(*e*) A large medulla, or pith, consisting of a hollow cylinder of cellular tissue, from which proceed numerous thin diaphragms toward the centre of the stem.

The structures above referred to may undoubtedly exist in different proportions in different species, and also in the same species in different parts, and at different stages of growth. In the woody axis more particularly, there is evidence that in such forms as *S.* (*Favularia*) *elegans*, the scalariform, or pseudo-scalariform, tissues were predominant. In young stems also, and in roots, this would probably be the case; and in the latter the texture was much coarser than in the stem: and, further, Prof. Williamson has shown me specimens from the Lancashire coal-field, which I have no doubt are Sigillarioid trees of the type of *S. vascularis* of Binney, and which, instead of a *Sternbergia* pith, have scalariform cells and vessels in the centre, and in which the bundles of scalariform vessels traversing the wood are included in considerable masses of cellular tissue, elongated vertically, like medullary rays. This plant presents external markings of the *Clathraria*-type. Mr. Carruthers has also shown me a specimen ribbed externally, and apparently a *Sigillaria* or *Syringodendron*, which shows only a cylinder of large scalariform fibres similar to those of *Stigmaria*. These facts show how wide differences may exist in the structures of stems referred by their superficial markings to *Sigillaria*.

In the case of specimens showing structure merely, it will undoubtedly require much further investigation to enable us always to distinguish the structures characteristic of the subgenera of *Sigillaria,* or absolutely to separate these from those of certain peculiar conifers on the one hand and from those of the higher acrogens on the other. Young and succulent stems of *Dadoxylon* may have much resembled *Sigillaria* in their structure. Young stems of *Sigillaria* proper may have approached closely to those of *Favularia*; and since I have shown* that the branches of *Favularia* resemble *Clathraria* in their scars, this last may have presented a still feebler type of internal organization. Further, there is, as I have already stated, reason to believe that some of the species referred by palæobotanists to the *Clathraria*-division are really forms of *Lepidophloios.* These difficulties, in connexion with the defective state of preservation of specimens, may excuse many differences of opinion, though I think the facts already stated in this paper are sufficient to put all students of the subject on the right track in regard to at least one leading type of these plants, and to remove some of the more fruitful sources of error.

We may now proceed to inquire what light the structures of *Sigillaria* throw on its affinities. On this question, taken in its most general aspect, there have, I believe, in modern times been only two opinions, the views as to alliance with *Euphorbiæ* and *Cacti* held by some older botanists having been given up. Some botanists, conspicuous among whom is Brongniart, hold that *Sigillariæ* were gymnospermous plants, allied to Cycadaceæ. Others are disposed to regard them as acrogens, and as closely related to Lycopodiaceæ.

In favour of the latter view may be urged the apparent association with *Sigillaria* of certain strobiles resembling those of *Lepidophloios,* the points of resemblance between the tissues of *Favularia elegans* and those of *Lepidodendron,* and the resemblance of certain *Sigillariæ,* or supposed *Sigillariæ,* of the *Clathraria*-type to *Lepidophloios.*

In favour of the former view, we may adduce the exogenous structure of the stem of *Sigillaria,* and the obvious affinity of its tissues to those of Conifers and Cycads, as well as the constant association with trees of this genus of the evidently phanerogamous fruits known as *Trigonocarpum* and *Cardiocarpum.* On the other hand, the resemblance to *Lepidodendron* may be shown to depend merely on comparisons of a part of the tissues of *Sigillaria* with those of that genus. Grave doubts may also be entertained as to whether strobiles of *Lepidophloios,* and even stems of that genus have not been improperly mixed up with *Sigillaria.*

It is probable that all botanists who have studied these plants, might agree that, if not Gymnosperms, they at least present points of affinity with them, and might be regarded as in some sense a link connecting them with Acrogens. Supposing this much to be admitted, important questions remain as to their possible relations to the modern Conifers and Cycads. The higher *Sigillariæ* unquestionably resemble Cycads in the structure of their stems. Their long rigid narrow leaves may be compared to single pinnæ of the leaves of Cycads. Their cord-like rootlets, as I have ascertained by actual comparison, are similar to those of Cycads. If their fruit was of the nature of *Cardiocarpum* or *Trigonocarpum*, this also would correspond. They differed principally in the division of the stem below into those remarkable underground branches, the *Stigmariæ*, and in the great upward extension and, in some instances at least, ramification of the stem. The former may be regarded as a special modification connected with their peculiar habitat. The latter may be interpreted as a modification either tending backward to the Lycopodiaceæ or forward to the Coniferæ. Since, so far as we at present know, the ramification prevails chiefly in the lower forms, the former may be the more correct view. It is even possible that the *Sigillariæ* may include forms bridging over the space between the higher Acrogens and the Gymnosperms. Viewed in this way, the typical ribbed *Sigillaria* point downwards through *Calamodendron* and *Calamites* to the Equisetaceæ, and the *Favularia*- and *Clathraria*-types point through *Lepidophloios* and *Lepidodendron* to Lycopodiaceæ. In the upward direction their affinities point both towards Conifers and Cycads. As our knowledge of the structure of individual species of *Sigillaria* increases, we may hope more certainly to trace the links of these affinities. It is, however, to be observed here, by way of caution, (1) that, of the plants reckoned among the several genera or subgenera of *Sigillariæ*, some may eventually prove to be gymnospermous and some cryptogamous, and (2) that, as we shall find in the next group to have been actually the case, some of these plants may, with a cryptogamous fructification, have presented a structure of stem more complex than that found in modern plants of similar grade.

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* "Conditions of Deposition of Coal," Quart. Journ. Geol. Soc. vol. xxii. p. 130.

2. Calamodendron and Calamites.

Calamites are among the most abundant fossils of the Carboniferous period, and occur also in the Devonian; and from their peculiar habitat and mode of growth, they are not only preserved as flattened stems, but also occur in immense numbers standing on the beds on which they grew.

They have naturally been regarded from the first as allied to Equisetaceæ; and this opinion is ably and, indeed, conclusively maintained by Schimper in his recent work*, and has been illustrated by the recent description of the fruit by Mr. Carruthers. Difficulties have, however, arisen from the fact that some stems regarded as Calamites have been found to be surrounded by a thick woody cylinder composed of discigerous and pseudo-scalariform tissue, similar to that of the type of *Sigillaria* above described. Some botanists have regarded these last as distinct from the true *Calamites*, and have placed them in the genus *Calamitea*, Cotta, or *Calamodendron*, Brongniart; and Williamson has recently proposed the name *Calamopitus*[*] for a group believed to be intermediate between *Calamodendron* and true *Calamites.* On still other grounds, *Bornia* and other genera or subgenera have been separated from *Calamites* proper. Latterly Schimper has endeavoured to combine the view of the Equisetaceous affinities and annual growth of the stems of *Calamites* with what, at first sight, seems the totally irreconcilable woody character of the stem of *Calamodendron* as described by Cotta, Dawes, and Binney.

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* Paléontologie Végétale.

In all my own publications on this subject, from the date of my first paper on *Calamites* published in the Journal of this Society[†], I have held that Calamites proper are Equisetaceous plants, having the external characters of their stems preserved, and that in the last respect they differ from the internal casts which belong to *Calamodendron.* All my subsequent observations have served to confirm these conclusions, which I would now illustrate by the following considerations.

1. The true *Calamites* (e. g. *C. Suckovii, C. cannæformis, C. Cistii,* &c.), when well preserved, present, externally, somewhat flat smooth striated ribs, with distinct nodes, and having, at the upper end of each rib, a rounded areole with a central dot or scar, marking the disarticulation of a leaf, branchlet, or root, or, in some cases, the extremity of one of those radial prolongations of the pith which have been described by Williamson. In one specimen in my possession there is a double set of marks—smaller ones on the node, apparently belonging to the appendages, and larger marks below the node, which may represent the radial prolongations of the pith (Pl. X. fig. 22). The cortical investment is very thin and dense, and presents externally the characters of an epidermis, not showing, as in the case of *Sternbergia* or *Calamodendron,* a coating of woody fibres externally, and therefore cannot be regarded as a mere medullary sheath or, as Schimper supposes, the membrane lining the hollow interior of the stem. I may remark here, that erect Calamites are sometimes surrounded by a calcareous or ferruginous concretionary coating which must not be confounded with the true surface of the stem.

2. The ordinary Calamites are seen to stand erect, rooted *in situ,* and attached together at the bases, or arising from rhizomata. The stems can be seen to bud from each other; and the roots can be traced proceeding from their bases and lower nodes. Figures of erect specimens were given in my paper on Erect Calamites, and also in that on the South Joggins[‡]. Abundant specimens may be obtained in the magnificent petrified Calamite brakes at the last-mentioned locality, and, I venture to say, cannot be studied by any geologist without producing the conviction that the erect cylindrical casts imbedded in groups in the sandstone must represent the true external form of the plant. I have also shown, in the paper above cited, that these erect stems are crushed by lateral pressure, and broken down

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[*] Preoccupied by Unger for certain Devonian plants.

[†] On the Occurrence of Upright Calamites near Pictou, Nova Scotia, Quart. Journ. Geol. Soc. vol. vii. p. 194.

[‡] Quart. Journ. Geol. Soc. vol. vii. p. 194, and vol. x. p. 1.

and flattened at the top, exactly as somewhat strong fistulous stems would be. It is obviously impossible that casts of medullary cavities could be preserved in this manner. Neither *Sternbergiæ* nor casts of the pith of *Calamodendra* ever occur under such circumstances.

3. The stems of *Calamites* may be seen to have produced leaves and branchlets in such a manner as to prove that they are complete stems preserving their external surface. In my paper on the South Joggins, I figured and described the leaves of *C. Cistii* as seen attached to the erect stems. I have since, in 'Acadian Geology,' figured those of *C. Suckovii*, found under similar circumstances; and I have specimens which appear to me to verify the figure given by Lindley and Hutton of the leaves of *C. nodosus*. I have also obtained beautifully preserved specimens of the leaves of *C. transitionis*, a species common to the Devonian and Lower Carboniferous. It has been supposed that the scars on the nodes of *Calamites* are merely the marks of bundles of vessels passing from the interior towards the surface; but it is obvious that, in the case of stems actually producing leaves and branchlets, this cannot be the true explanation, though after seeing the very instructive slices of Prof. Williamson's *Calamopitus*, kindly shown to me by him, I am prepared to admit that in some specimens, at least, they may represent the "medullary radii," which, as already stated, sometimes appear *in addition to* the true vascular scars.

4. The leaves of *Calamites* were not, as is often stated, identical with those of *Asterophyllites*; and the genus *Calamocladus*, in which Schimper has placed many plants of the latter genus, is therefore altogether unnecessary. A careful microscopic examination of the leaves which I have found attached to Calamites convinces me that they have distinct characters, and affords an additional link of connexion with Equisetaceæ. The leaves of *Asterophyllites* proper are flat, expanded in the middle, and with a distict midrib. Those of *Calamites* are strictly linear, thick, and angled, and are besides marked with transverse lines or striæ. Similar transverse lines occur on the branchlets of some modern *Equiseta*, and are produced by lines of minute stomata. Well-preserved specimens of Calamite-leaves have precisely the same appearance, so that they may be compared to branchlets of *Equiseta* deprived of their sheath. Flattened leaves of *Calamites*, it is true, sometimes present the appearance of a midrib; but this arises either from the prominence of the upper angle, or the appearance of an internal axis through the substance of the leaf. Unless very badly preserved, they can always be distinguished from *Asterophyllites* or *Annularia*. The connexion supposed, by Ettingshausen and others, to obtain between *Calamites* and *Asterophyllites* has arisen either from accidental association, or from failure to distinguish leaves and stems of *Calamites* from the corresponding parts of *Asterophyllites**. The conjecture of Brongniart that some, at least, of the *Asterophyllites* may be leaves, not of

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* The species *Asterophyllites comosus*, L. v. H., appears to consist of, or to include, leaves of *Calamites*; and there is reason to doubt whether the proper *Asterophyllites* should be separated from *Annularia*.

Calamites, but of *Calamodendron*, rests on different grounds, and is supported by the fact that some of the larger stems which may be supposed to represent the external surface of *Calamodendron*, have tumid nodes similar to those of the branches of *Asterophyllites*. Stems of this kind are sometimes found in an erect position in the Coal-measures of Nova Scotia, and are manifestly distinct from those of ordinary Calamites.

5. The microscopic structure of *Calamites* is not precisely identical with that of *Calamodendron*, though the latter may be regarded as a more advanced type of the former. The Calamites have a thin outer coat with lacunæ, or air-cells, like those of modern *Equiseta*; and the tissue intervening between these contains large vasiform tubes marked on the surface with numerous rows of small pores ("multiporous tissue" of my papers on the Structures in Coal, &c.), and which bear some resemblance to the fibres of *Dictyoxylon* as described by Williamson (Pl. IX. fig. 19). This structure has been illustrated by Goeppert, Unger, Schimper, and others; and I have verified it by the microscopic examination of numerous flattened Calamite-stems in the shales and coarse coals. Facts of this kind kind were mentioned in my paper on the 'Structures in Coal.'

The *Calamodendra*, on the other hand, are casts of the medullary cavities of stems having a thick woody envelope disposed in wedges separated by intervening tracts of cellular tissue, which, according to Williamson, are of the nature of large medullary rays, while smaller medullary rays occur in the intervening wedges, and presenting the same discigerous and pseudo-scalariform tissues observed in *Sigillaria*. I have represented in Plate IX. two forms of *Calamodendron* with the tissues found attached to them. These stems, no doubt, have lacunæ like those of Calamites, and resemble them in general arrangement of parts, but differ in the much greater development of the woody tissue, and, in some species at least, in the character of this tissue.

6. The fructification of Calamites I have not found in connexion with the stems. I have no doubt, however, that some of the spikes of fructification described by authors as the fruit of *Calamites*, really belong to these plants. There has, however, been some confusion between the fruit of *Calamites* and *Asterophyllites*, which demands attention from those who have access to the specimens.

It results from the facts above stated that the true equisetaceous Calamites are well known to us by their external forms, habit of growth, and foliage, as well as by their internal structure; and on all these grounds no reasonable doubt can be entertained as to their affinities. Whether, as Schimper supposes, they were merely annual stems like those of modern *Equiseta*, admits of more doubt. In the equable climate of the Coal-period such stems may have continued growing from year to year. Nor do I think that their rhizomata were relatively so important as those of *Equiseta*. In some of the species, at least, the erect stem itself, fortified by adventitious roots, and partly buried by increasing deposits of sediment, seems to have served the purpose of a rhizoma*. The best example that I have seen of the rhizoma of a Calamite is that figured in Plate IX. (fig. 21), from a specimen presented by me to the Geological Society many years ago.

With regard to *Calamodendron* the difficulties are greater, and have been well stated by Prof. Williamson in a recent paper in the 'Memoirs of the Literary and Philosphical Society of Manchester'†, in which he describes under the generic name *Calamopitus* a peculiar stem, which, while he identifies it in its general characters with *Calamites,* he justly regards as being in internal structure distinct from the *Calamodendra* described by Cotta and Binney.

The characters of *Calamodendron* as distinguished from ordinary *Calamites* may be summed up as follows:—

(*a*) The part usually preserved is the internal axis, corresponding to a *Sternbergia.* It presents ribs similar to those of *Calamites,* but more angular, and almost always having traces of woody fibres capable of showing the structure on some part of their surface. I have not seen on these casts any distinct traces of scars or areoles. These casts of the pith of *Calamodendron* constitute the greater part, if not the whole of the specimens referred to *C. approximatus.*

(*b*) More complete specimens are invested with woody matter, arranged in wedges, and consisting of elongated cells and porous, discigerous, or pseudo-scalariform tissue. My specimens do not show distinctly the arrangement of these; but this has been well described by other observers. Williamson describes medullary rays in the woody bundles in addition to the large cellular tracts intervening between them.

(*c*) The actual external surface of *Calamodendron* is not certainly known; but I have been disposed to regard as of this kind those ribbed stems, found in the coal-formation, which have swollen nodes as if caused by the emission of whorls of small branches. I have specimens of these in my collection, which I have hesitated to name or describe until they could be better understood. Prof. Williamson's description of *Calamopitus* now inclines me to suppose that they belong to that genus or to allied forms.

With regard to the affinities of the *Calamodendra,* the structure of the stem raises them above the Calamites and modern *Equiseta,* and justifies the conjecture of Brongniart that they may have been gymnosperms. Williamson, Carruthers, and Binney, however, attribute to them a cryptogamous fructification. In this case they may, as the former suggests, be a connecting link between Acrogens and Gymnosperms. Should subsequent investigations confirm this view, it will throw an interesting light on the possible affinities of *Sigillaria. Calamites,* on the one hand, and *Lepidodendron* on the other, are distinctly cryptogamous and are related to, or included in, the modern families of Equisetaceæ and Lycopodiaceæ. But *Calamodendron* seems to form a connecting link between *Calamites* and the ribbed *Sigillariæ*; and in like manner *Lepidophloios* seems to connect the

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* See my description in Quart. Journ. Geol. Soc. vol. x.

† Vol. iv. 3rd Series.

Lepidodendra with the *Sigillariæ* of the *Favularia*-type. On the other hand, as already stated under *Sigillaria*, the ribbed *Sigillariæ* may be related through *Ormoxylon* and *Dadoxylon* to the modern Conifers, and the *Favulariæ* may be related to the Cycads. This relationship may be expressed as follows:—

Cycadaceæ. *Coniferæ.*
Dadoxylon.
Favularia? Palæoxylon.
Ormoxylon †.
Dictyoxylon.

SIGILLARIA.
Rhytidolepis. Calamodendron.
Favularia? Calamopitus.
Clathraria. Bornia.
Syringodendron. Calamites.
Lepidophloios. *Equisetaceæ.*
Lepidodendron *.
Lycopodiaceæ.

I do not give this Table with any view to theories of derivation, but merely as an expression of probable affinities among these very curious and ancient types of vegetation.

I may add here a few words with reference to *Sphenophyllum*, a genus which some authors unite with *Calamites*. The verticillate, cuneate, veiny leaves of this plant, and its spikes of fructification have long been known; and in 1865 I was enabled by a specimen in the collection of Sir W. E. Logan to determine the structure of its stem, which contains a slender axis of reticulato-scalariform vessels of the type of those in *Tmesipteris*‡. These plants obviously had no connexion with *Calamites* or *Calamodendron*, but constitute a peculiar synthetic type, presenting points of resemblance to Ferns and Marsiliaceæ.

In conclusion, and with reference to my former papers on the "Structures in Coal," I would repeat the statement made in those papers, that the tissues of *Sigillaria*, as defined in this paper, and of *Calamodendron* enter more largely than any others into the composition of the mineral charcoal, and other parts retaining structure, of the coal of Nova Scotia; and I have reason to believe that similar tissues are at least very abundant in the coal of this country.

Supplementary Note.—Owing to the delay in the publication of tho above paper, it is necessary to add the following statements:—

(1) Prof. Williamson has described another type of Calamitean stem, which he regards as intermediate between his *Calamopitus* and *Calamodendron* §, but which has the *reticulated* or *multiporous* vessels of the former. To Prof. Williamson is due the credit of recognizing this structure for the first time in English specimens, though, as above

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* Including *Sagenaria*.

† Dawson, MS.

‡ Quart. Journ. Geol. Society, May 1866.

§ Manchester Lit. and Phil. Soc. Proceedings, 1870.

stated, it had previously been well known elsewhere. I regard these plants, so well described by Williamson, as true *Calamites*, in the sense in which that word is used above.

(2) The same palæobotanist has independently expressed the belief above stated, that the leaves of *Calamites* are distinct from those of *Asterophyllites*, and has also stated a distinction between those so-called *Volkmanniæ* which may be regarded as fruits of *Calamites* and those which belonged to *Asterophyllites* *. He has also described a specimen of *Stigmaria* showing the medullary rays, and otherwise approaching to the structures which should be found in the roots of the typical *Sigillariæ* above described.

(3) Schimper, in his 'Paléontologie Végétale,' vol. xi., has treated the *Sigillariæ* very slightly. He adds no new facts of importance to their history, does not separate them from the plants of the genus *Lepidophloios*, usually mixed with them, refers the whole to one genus, and places them with the Lycopodiaceæ.

(4) Binney, in the Palæontographical Society's Publications, vol. xxiv., has described, under the name of *Bowmanites cambrensis*, a very interesting plant, which I regard as a typical member of the group *Asterophylliteæ*, as distinguished from *Calamiteæ*.

(5) Attention having been directed by Prof. Huxley to the presence of *spore-cases* in Coal, I have endeavoured to show, in a paper in the 'American Journal of Science' for April, that these bodies are not a large constituent of ordinary Coal, and that any importance which they possess in this respect is due to their identity in chemical composition with those *cortical* and *epidermal* tissues which, like the *suberin* of cork, are more nearly allied in composition to Coal than any other recent vegetable matters, and better fitted, by their chemical and mechanical properties, for its production.

EXPLANATION OF THE PLATES.

Plate VII.

Fig. 1. *Sternbergia*, pith of *Dadoxylon*; 1 *a*, section of one side, showing diaphragms; 1 *b*, section of a diaphragm and three wood-cells, magnified; 1 *c*, two wood-cells, highly magnified, showing reticulated walls.

2. *Sternbergia*, pith of *Sigillaria*, natural size; 2 *a*, 2 *b*, discigerous tissue investing the same.

3. *Sternbergia*, pith of *Sigillaria*, natural size; 3 *a*, discigerous and scalariform tissue.

4. *Sternbergia*, natural size; 4 *a*, reticulato-scalariform tissue.

5. *Sternbergia*, natural size; 5 *a*, 5 *b*, scalariform and reticulato-scalariform tissue.

6. Scalariform vessel of *Lepidophloios*.

Plate VIII.

Fig. 7. *Sternbergia*, of Lepidodendroid tree?, natural size; 7 *a*, scalariform tissue.

8. Section of a flattened stem (*Sigillaria*?) 1 foot in diameter, converted into coal, with *Sternbergia*-pith.

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* Manchester Lit. and Phil. Soc. Proceedings, Feb. 1871.

Fig. 9. *Sternbergia*, pith of the same, natural size; 9 *a*, discigerous tissue of the same.
10. Another stem, probably Coniferous, with *Sternbergia* pith.
11. Woody tissue of prostrate *Sigillaria*; 11 *a*, bast-tissue of the same.
12. Woody tissue of a *Sigillaria*; 12 *a*, medullary ray.
13. Tissue of a *Sternbergia* similar to fig. 9.
14, 15, 16. Discigerous tissue of erect trees (*Sigillariæ*) in mineral charcoal.

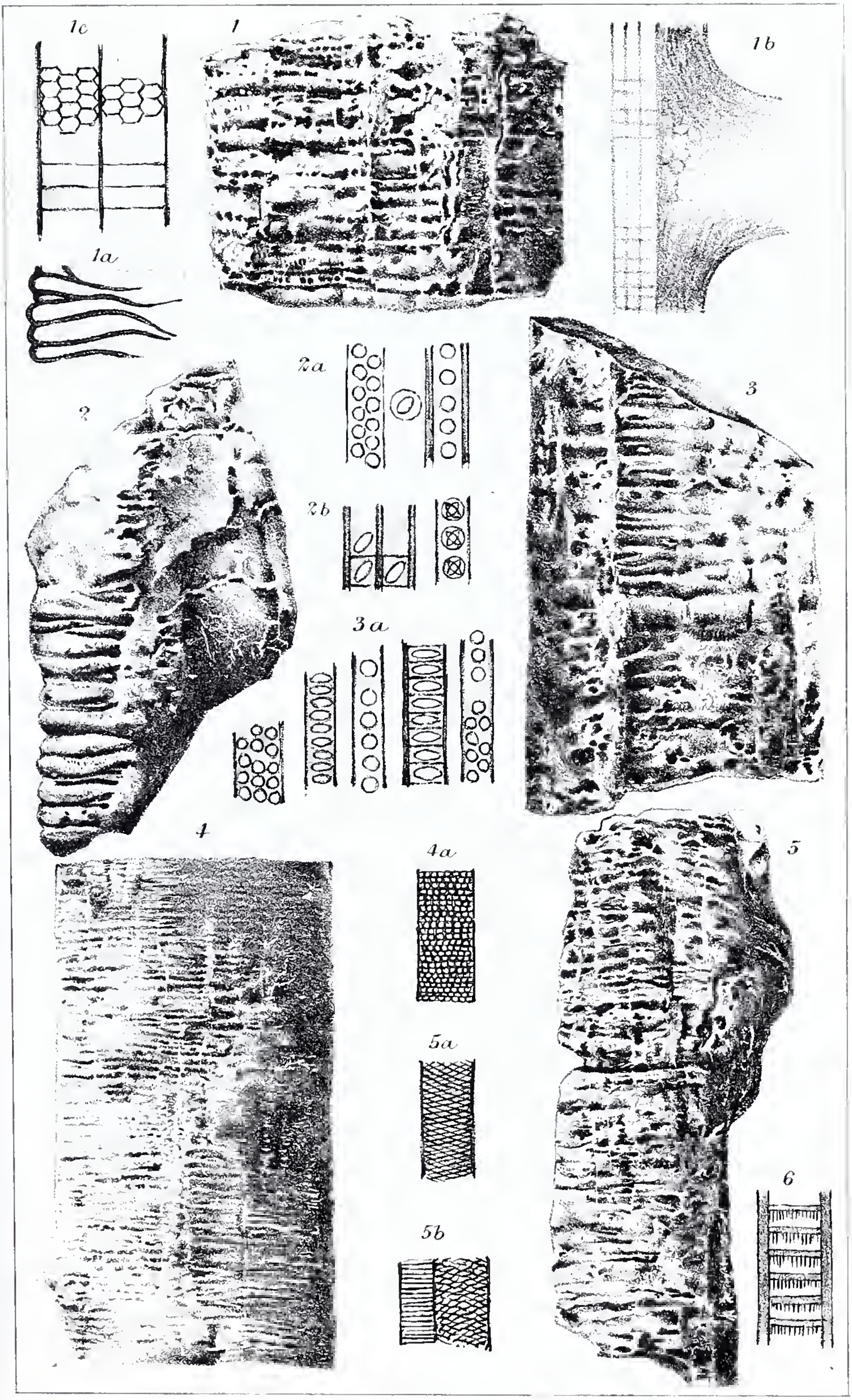
PLATE IX.

Fig. 17. *Calamodendron approximatum*, cast of pith; 17 *a*, 17 *b*, discigerous and scalariform tissue of the same.
18. *Calamodendron* invested with woody tissue: A, pith; B, woody cylinder; 18 *a*, cross section; 18 *b*, cross section, magnified, showing compression of the tissue; 18 *c*, discigerous and pseudo-scalariform tissue of the same.
19. Portion of a multiporous vessel of a true *Calamites*, magnified to the same scale with figs. 17 *a* & 17 *b*.
20. Stem of erect *Calamodendron* (S. Joggins, Nova Scotia), showing its external surface, one-third nat. size.
21. Base of stem of *Calamites* (S. Joggins), showing rhizoma, reduced.
22. Node of *Calamites*, showing scars of verticillate branchlets and of radial processes.

PLATE X.

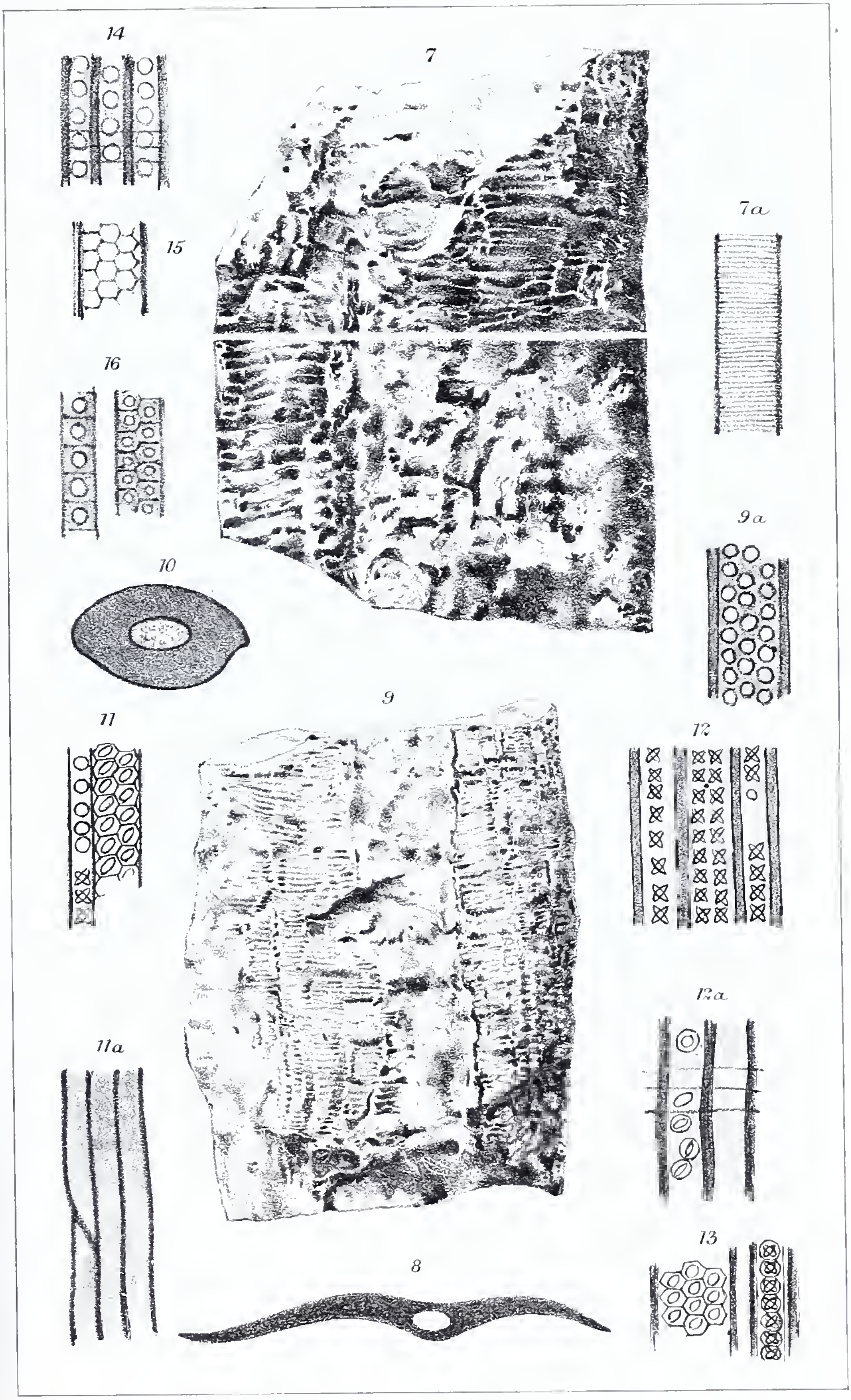
Fig. 23. Radial section of stem of *Sigillaria* of the type of *S. Brownii*, Dawson, restored, natural size: *a*, pith; *b*, woody cylinder; *c*, cellular inner bark; *d*, fibrous bark; *e*, outer cortical layer.
24. Radial section of the woody cylinder, magnified (letters as above); and portions of the tissues more highly magnified below: *b* 1, inner pseudo-scalariform cylinder; *b* 2, 3, 4, discigerous outer cylinder.
25. Radial section, more highly magnified, showing one of the radiating bundles of vessels (this section has been inverted); 25 *a*, single pseudo-scalariform vessel from radiating bundle.
26. Tangential section of the same stem, showing the woody fibres and one of the radial bundles, and the medullary rays.
27. Tangential section showing woody fibres and medullary rays, more highly magnified.
28. Radial arrangement of woody fibres, magnified.
29. Fibres or elongated cells of the bark (*d*).

Note.—All the drawings of *separate fibres and vessels* in the above figures are on one scale.



W.G. Smith lith.
Mintern Bros imp.

STERNBERGIA



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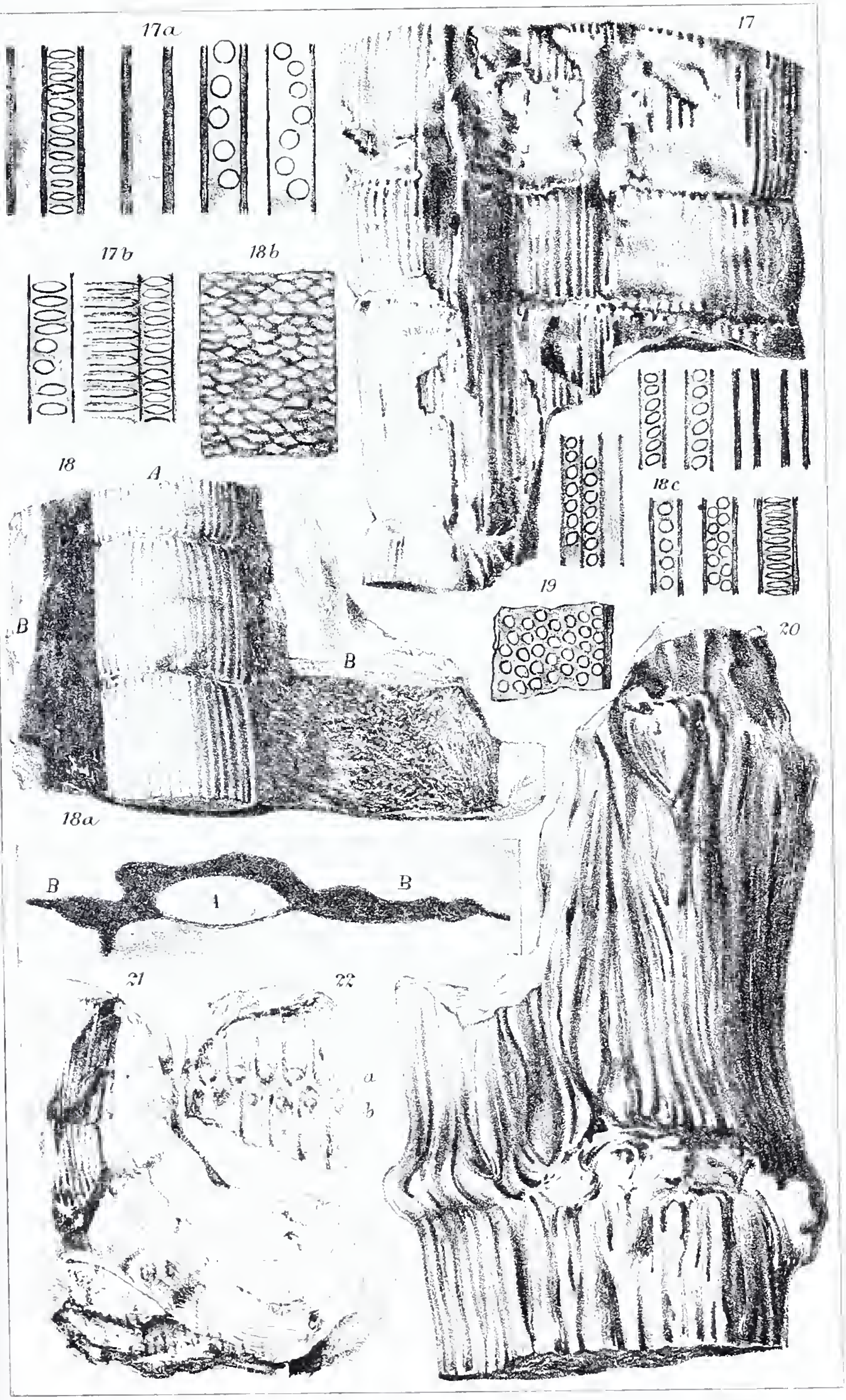

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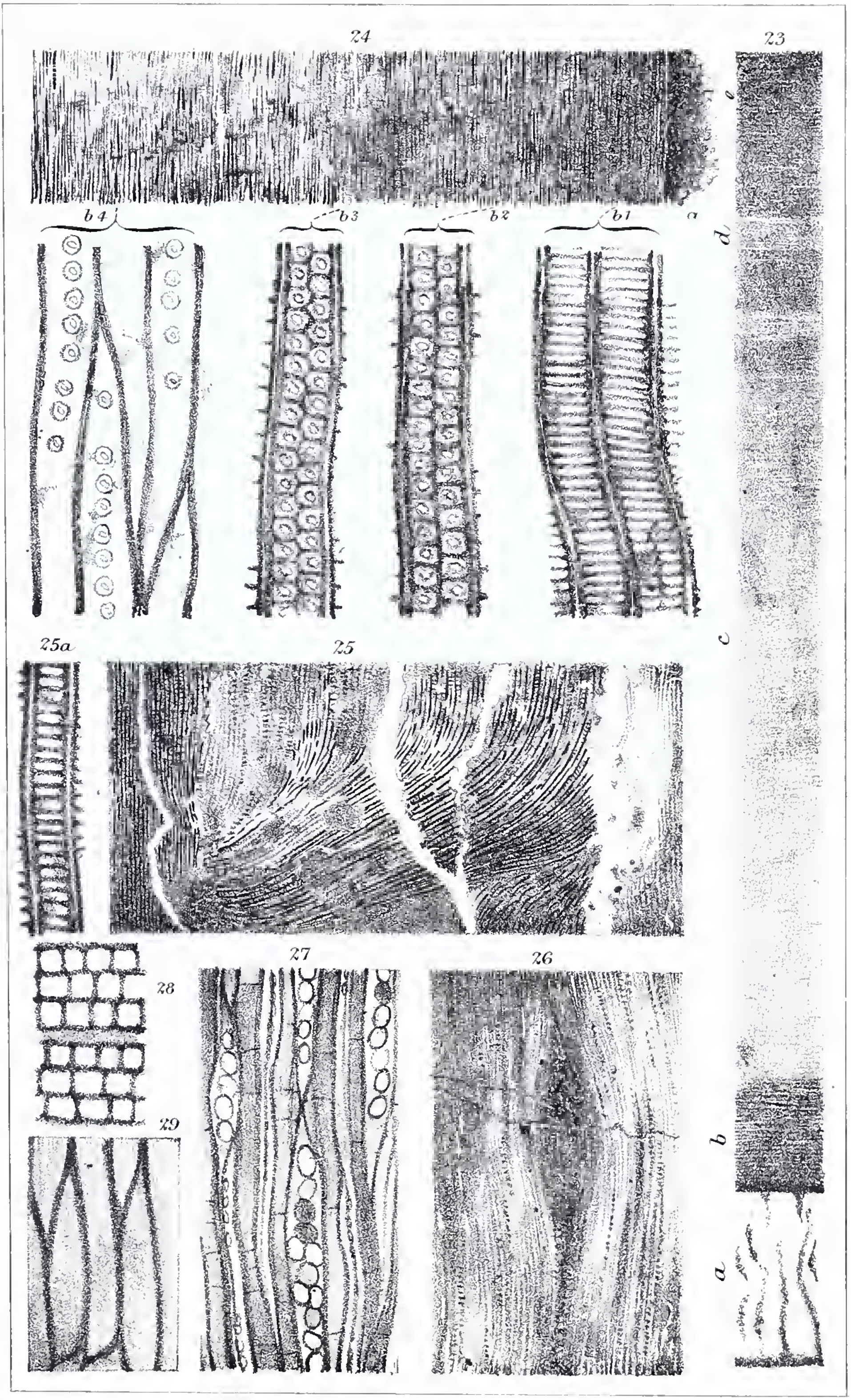
CALAMODENDRON & CALAMITES.



W. G. Smith lith.
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SIGILLARIA.

[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for February* 1870.]

ON

THE GRAPHITE

OF

THE LAURENTIAN OF CANADA.

BY

J. W. DAWSON, LL.D., F.R.S., F.G.S.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

In my paper of 1864, on the Organic Remains of the Laurentian Limestones of Canada, as a sequel to the description of *Eozoon Canadense*, I noticed, among other indications of organic matters in these limestones, the presence of films and fibres of graphitic matter, and insisted on the probability that at least some of the lower forms of plant life must have existed in the seas in which gigantic Foraminifera could flourish. Dr. Hunt had previously, on chemical evidence, inferred the existence of Laurentian vegetation*, and Dana had argued as to the probability of this on various grounds†; and my object in referring to these indications in 1864, as well as to the supposed burrows of annelids, subsequently described by me‡, was to show that the occurrence of *Eozoon* was not to be regarded as altogether isolated and unsupported by probabilities of the existence of organic remains in the Laurentian deducible from other considerations.

Now that the questions which have been raised regarding *Eozoon* may be considered settled, not only by the adhesion of the greatest authorities in palæontology and zoology, but by the discovery of similar organisms in rocks of the same age elsewhere, by specimens preserved in such a manner as to avoid all the objections raised to the mineral condition of the fossil*, and by the discovery of such modern analogies as that furnished by *Bathybius*, it may be proper to invite the attention of geologists more particularly to the evidence of vegetable life afforded by the deposits of graphite existing in the Laurentian.

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* 'American Journal of Science' (2), xxxi. p. 395. From this article, written in 1861, after the announcement of the existence of laminated forms supposed to be organic in the Laurentian, by Sir W. E. Logan, but before their structure and affinities had been ascertained, I quote the following sentences:—"We see in the Laurentian series beds and veins of metallic sulphurets, precisely as in more recent formations; and the extensive beds of iron-ore, hundreds of feet thick, which abound in that ancient system, correspond not only to great volumes of strata deprived of that metal, but, as we may suppose, to organic matters which, but for the then great diffusion of iron-oxyd in conditions favourable for their oxydation, might have formed deposits of mineral carbon far more extensive than those beds of plumbago which we actually meet in the
n strata. All these conditions lead us then to conclude the existence
ant vegetation during the Laurentian period."

f Geology. I may also be permitted to refer to my own work
8, and Appendix D, 1860.

n. Geol. Soc. vol. xxii. p. 608.

The graphite of the Laurentian of Canada occurs both in beds and in veins, and in such a manner as to show that its origin and deposition are contemporaneous with those of the containing rock. Sir William Logan states† that "the deposits of plumbago generally occur in the limestones or in their immediate vicinity, and granular varieties of the rock often contain large crystalline plates of plumbago. At other times this mineral is so finely disseminated as to give a bluish-gray colour to the limestone, and the distribution of bands thus coloured, seems to mark the stratification of the rock." He further states:—"The plumbago is not confined to the limestones; large crystalline scales of it are occasionally disseminated in pyroxene rock or pyrallolite, and sometimes in quartzite and in feldspathic rocks, or even in magnetic oxide of iron." In addition to these bedded forms, there are also true veins in which graphite occurs associated with calcite, quartz, orthoclase, or pyroxene, and either in disseminated scales, in detached masses, or in bands or layers "separated from each other, and from the wall rock by feldspar, pyroxene, and quartz." Dr. Hunt also mentions the occurrence of finely granular varieties, and of that peculiarly waved and corrugated variety simulating fossil wood, though really a mere form of laminated structure, which also occurs at Warrensburgh, New York, and at the Marinski mine in Siberia. Many of the veins are not true fissures, but rather constitute a net-work of shrinkage cracks or segregation veins traversing in countless numbers the containing rock, and most irregular in their dimensions, so that they often resemble strings of nodular masses. It has been supposed that the graphite of the veins was originally introduced as a liquid hydro-carbon. Dr. Hunt, however, regards it as possible that it may have been in a state of aqueous solution‡; but in whatever way introduced, the character of the veins indicates that in the case of the greater number of them the carbonaceous material must have been derived from the bedded rocks traversed by these veins, while there can be no doubt that the graphite found in the beds has been deposited along with the calcareous matter or muddy and sandy sediment of which these beds were originally composed.

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* I cannot, after examination of the specimen, and of others subsequently obtained by Sir W. E. Logan, attach any value to the supposition of Messrs. Rowney & King that the Tudor specimen has been produced by infiltration of carbonate of lime into veins. The mechanical arrangement of the laminæ and their microscopic structure forbid such a supposition, as well as the comparison of them with actual calcareous veins occurring in the same rock.

† 'Geology of Canada,' 1863.

‡ 'Report of the Geological Survey of Canada,' 1866.

The quantity of graphite in the Lower Laurentian series is enormous. In a recent visit to the township of Buckingham, on the Ottawa River, I examined a band of limestone believed to be a continuation of that described by Sir W. E. Logan as the Green Lake Limestone. It was estimated to amount, with some thin interstratified bands of gneiss, to a thickness of 600 feet or more, and was found to be filled with disseminated crystals of graphite and veins of the mineral to such an extent as to constitute in some places one-fourth of the whole; and making every allowance for the poorer portions, this band cannot contain in all a less vertical thickness of pure graphite than from 20 to 30 feet. In the adjoining township of Lochaber Sir W. E. Logan notices a band from 25 to 30 feet thick, reticulated with graphite veins to such an extent as to be mined with profit for the mineral. At another place in the same district a bed of graphite from 10 to 12 feet thick, and yielding 20 per cent. of the pure material, is worked. When it is considered that graphite occurs in similar abundance at several other horizons, in beds of limestone which have been ascertained by Sir W. E. Logan to have an aggregate thickness of 3500 feet, it is scarcely an exaggeration to maintain that the quantity of carbon in the Laurentian is equal to that in similar areas of the Carboniferous System. It is also to be observed that an immense area in Canada appears to be occupied by these graphitic and *Eozoon*-limestones, and that rich graphitic deposits exist in the continuation of this system in the State of New York, while in rocks believed to be of this age near St. John, New Brunswick, there is a very thick bed of graphitic limestone, and associated with it three regular beds of graphite, having an aggregate thickness of about 5 feet*.

It may fairly be assumed that in the present world and in those geological periods with whose organic remains we are more familiar than with those of the Laurentian, there is no other source of unoxidized carbon in rocks than that furnished by organic matter, and that this has obtained its carbon in all cases, in the first instance, from the deoxidation of carbonic acid by living plants. No other source of carbon can, I believe, be imagined in the Laurentian period. We may, however, suppose either that the graphitic matter of the Laurentian has been accumulated in beds like those of coal, or that it has consisted of diffused bituminous matter similar to that in more modern bituminous shales and bituminous and oil-bearing limestones. The beds of graphite near St. John, some of those in the gneiss at Ticonderoga in New York, and at Lochaber and Buckingham and elsewhere in Canada are so pure and regular that one might fairly compare them with the graphitic coal of Rhode Island. These instances, however, are exceptional, and the greater part of the disseminated and vein graphite might rather be compared in its mode of occurrence to the bituminous matter in bituminous shales and limestones.

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* Matthew in 'Quart. Journ. Geol. Soc.' vol. xxi. p. 423. Acadian Geology, p. 662.

We may compare the disseminated graphite to that which we find in those districts of Canada in which Silurian and Devonian bituminous shales and limestones have been metamorphosed and converted into graphitic rocks not dissimilar to those in the less altered portions of the Laurentian*. In like manner it seems probable that the numerous reticulating veins of graphite may have been formed by the segregation of bituminous matter into fissures and planes of least resistance, in the manner in which such veins occur in modern bituminous limestones and shales. Such bituminous veins occur in the Lower Carboniferous limestone and shale of Dorchester and Hillsborough, New Brunswick, with an arrangement very similar to that of the veins of graphite; and in the Quebec rocks of Point Levi, veins attaining to a thickness of more than a foot, are filled with a coaly matter having a transverse columnar structure and regarded by Logan and Hunt as an altered bitumen. These palæozoic analogies would lead us to infer that the larger part of the Laurentian graphite falls under the second class of deposits above mentioned, and that, if of vegetable origin, the organic matter must have been thoroughly disintegrated and bituminized before it was changed into graphite. This would also give a probability that the vegetation implied was aquatic, or at least that it was accumulated under water.

Dr. Hunt has, however, observed an indication of terrestrial vegetation, or at least of subaerial decay, in the great beds of Laurentian iron-ore. These, if formed in the same manner as more modern deposits of this kind, would imply the reducing and solvent action of substances produced in the decay of plants. In this case such great ore beds as that of Hull, on the Ottawa, 70 feet thick, or that near Newborough, 200 feet thick†, must represent a corresponding quantity of vegetable matter which has totally disappeared. It may be added that similar demands on vegetable matter as a deoxidizing agent are made by the beds and veins of metallic sulphides of the Laurentian, though some of the latter are no doubt of later date than the Laurentian rocks themselves.

It would be very desirable to confirm such conclusions as those above deduced by the evidence of actual microscopic structure. It is to be observed, however, that when, in more modern sediments, Algæ have been converted into bituminous matter, we cannot ordinarily obtain any structural evidence of the origin of such bitumen, and in the graphitic slates and limestones derived from the metamorphosis of such rocks no organic structure remains. It is true that, in certain bituminous shales and limestones of the Silurian system, shreds of organic tissue can sometimes be detected, and in some cases, as in the Lower Silurian limestone of the La Cloche mountains in Canada, the pores of brachiopodous shells and the cells of corals have been penetrated by black bituminous matter, forming

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* Granby, Melbourne, Owl's Head, &c., 'Geology of Canada,' 1863, p. 599.

† Geology of Canada, 1863.

[*From the* Quarterly Journal *of the* Geological Society *for February* 1876.]

ON THE OCCURRENCE OF *EOZOON CANADENSE* AT CÔTE ST. PIERRE.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

NOTES *on the* OCCURRENCE *of* EOZOON CANADENSE *at* CÔTE ST. PIERRE.

By J. W. DAWSON, LL.D., F.R.S., F.G.S.

[PLATE X.]

CÔTE ST. PIERRE, in the Seigniory of Petite Nation, on the river Ottawa, is the locality whence some of the most instructive specimens of *Eozoon* were obtained by the late Mr. Lowe, whose collections are referred to in papers presented to this Society by Sir W. E. Logan and the writer. Believing that a reexamination of this place would afford a good opportunity for collecting additional specimens, and for the study of the fossil *in situ*, as well as for testing the validity of objections recently raised to the animal nature of *Eozoon*, I made arrangements for visiting it in September last; and, through the kindness of Mr. Selwyn, Mr. T. C. Weston, of the Geological Survey, a skilful collector, and who has had much experience in preparing and examining specimens of *Eozoon*, was permitted to accompany me, and subsequently prepared slices and photographs of some of the specimens obtained.

The Lower Laurentian rocks of this region have been carefully mapped and described in the Reports of the Geological Survey, to which I may refer for their general description. The limestone, which has afforded *Eozoon* at Cote St. Pierre, is a thick bed belonging to the Grenville band of Sir W. E. Logan, and included between the two great belts of orthoclase gneiss (the third and fourth gneiss) which in this region constitute the upper beds of the Lower Laurentian. Its average thickness, according to the measurements of Sir William Logan, is 750 feet; but it varies from 1500 feet to 60 feet. Its outcrop has been traced in the country north of the Ottawa for at least 100 miles, along several anticlinal and synclinal folds*.

At Cote St. Pierre this limestone occurs on the flank of a hill of gneiss and stratified diorite, with a dip to the south-east at angles of 70° to 80°. The dip, however, is very inconstant, owing to the contortions of the beds.

The limestone is white and crystalline, and may be described as thin-bedded, since it presents a great number of layers of no great individual thickness, and differing in the coarseness of the crystallization and in the presence of dolomite, serpentine, and layers of gneissose matter in some of them. The specimens of *Eozoon* were found to be abundant in only one bed, not more than four feet in thickness, though occasional specimens and layers of fragments occur in other parts of the band. The exposures are in part natural weathered surfaces seen on a wooded bank, in part an opening made by Mr. Lowe to extract specimens of *Eozoon*, and a larger opening made, as we were informed, by parties in search of fibrous serpentine, or "rock-cotton," for economic purposes.

* See map in 'Geology of Canada,' 1863.

The sections seen in the artificial exposures may be tabulated as follows, though from the highly inclined position of the beds and the irregularity of the excavations, perfect accuracy was not attainable:—

Mr. Lowe's Excavation (order descending).

1. Limestone with serpentine and entire specimens of *Eozoon*—3 feet.
2. Coarse crystalline limestone, with layers containing fragments of *Eozoon*—4 feet.
3. Limestone with concretions and layers of serpentine, and a few specimens of *Eozoon*—several feet, to the bottom of the excavation.

Fisher's Excavation (order descending).

1. Laminated limestone with bands of serpentine—6 feet.
2. White laminated limestone traversed by small veins of chrysotile—8 feet.
3. Limestone with concretions and interrupted bands of serpentine and pyroxene, and fragments of *Eozoon*—10 feet. (Crystals and layers of dolomite occur in this and the preceding beds.)
4. Limestone with large concretions of serpentine, and in one layer fine-grained variety of *Eozoon* (var. *minor*)—20 feet.
5. Limestone with serpentine and perfect specimens of *Eozoon*. (This probably corresponds to Lowe's excavation)—12 feet.
6. Coarse-grained limestone and dolomite—several feet.

(After a break of several yards)

7. Limestone with masses of pyroxene and veins of chrysotile and some imperfect *Eozoon*.

(After a break of several yards)

8. Coarse-grained diorite, resting on a thick band of gneiss.

In front of Lowe's excavation, and apparently overlying the limestone exposed in it, is a narrow ledge of fine-grained gneiss; and beyond this other and probably overlying limestone appears, holding pyroxene and mica. The whole vertical thickness of the limestone exposed can scarcely exceed 150 feet; but this is probably only a small part of the development of the band at this place.

In the strike of the limestone to the south it appears to bend abruptly, or to be thrown by a fault, to the south-east, the gneiss and diorite coming forward into a line with it, and the limestone appearing in a little bare knoll in front of these. On the surface of this limestone were found some fine specimens of weathered *Eozoon*.

I examined carefully the relation of the bedded serpentine and the veins of chrysotile or fibrous serpentine to the limestone. The compact serpentine is evidently an original part of the deposit, occurring in layers and lenticular concretions. In some beds it shows no indication of the structure of *Eozoon*; but in others it fills the cavities of the fossils, and there are many regular layers of fragmental *Eozoon* of considerable thickness in which it fills the cells, while in other layers interstratified with these the fossil is associated with dolomite. I satisfied myself on this point not only on the ground, but also by taking away large specimens representing several thin layers, and treating them with dilute acid so as to being out the structure. The following is a section of such a specimen, 5½ inches in vertical thickness, treated with acid and examined with a lens:—

1. Limestone with crystals of dolomite and a few fragments of *Eozoon*.
2. Fine-grained limestone with granules of serpentine—the latter filling the chamberlets of fragments of *Eozoon* and small globigerine Foraminifera.
3. Limestone with dolomite and including a thin layer of serpentine as above.
4. Limestone and dolomite with grains of serpentine and fragments of supplemental skeleton of *Eozoon*.
5. Crystallized dolomite, holding a few fragments of *Eozoon* in the state of calcite.
6. Limestone with disseminated serpentine as above, chamberlets of *Eozoon* and fragments of its supplemental skeleton, also small groups of chamberlets, perhaps globigerine Foraminifera.

In other specimens a like thickness of rock presented a mass of fragments of supplemental skeleton with the canals injected with serpentine, and granules of the same filling the chambers.

The chrysotile veins, which are sometimes an inch or more in thickness, but branch off into the most minute fibres, are evidently altogether subsequent in origin to the bedded limestone and serpentine. They are undoubtedly of aqueous origin, and in their mode of occurrence strongly resemble the veins of fibrous gypsum penetrating the Lower Carboniferous marls of Nova Scotia. They cross the bedding in all directions, and pass through the structure of *Eozoon*, though sometimes running parallel to its laminæ for short distances. They must have been introduced after the *Eozoon* was mineralized, and have evidently no connexion with its structure.

In the diagram (Pl. X. fig. 2) I have attempted to represent this relation; and I have no hesitation in stating that the assertion that these chrysotile veins are identical with or similar to the proper wall of *Eozoon* either in structure or distribution, is wholly without foundation, other than that which may arise from confounding dissimilar structures accidentally associated with each other.

Some slickensided joints lined with a lamellar and fibrous serpentine traverse the beds, and, as the chrysotile veins sometimes terminate in them, may be older than the latter. These also were observed to cross the masses of *Eozoon*.

Few disseminated minerals, other than those already mentioned, were observed in the *Eozoon* limestone. A few detached crystals of mica, pyroxene, and pyrite were found in the fragmental layers, and also a few rounded particles of quartz, probably grains of sand.

The perfect examples of *Eozoon*, at least those rendered evident by mineralization with serpentine, are confined to certain bands of limestone, and notably to one band—that originally opened by Mr. Lowe. In this bed the fossil occurs in patches of various sizes, some of them two feet or more in diameter, and bent or folded by the contortions of the strata; others are much smaller, down to a few inches. On the weathered surfaces the specimens mineralized with serpentine project, and exhibit their lamination in great perfection, resembling very closely the silicified *Stromatoporæ* of the Corniferous Limestone.

None of the specimens of *Eozoon* is of any great vertical thickness. The lower laminæ are generally the best developed and with the thickest supplemental or intermediate skeleton. The upper laminæ become thin-walled, though often very regular; and after about 100 laminæ at most, the superficial portions become acervuline for an inch or so and then terminate. In some specimens only a few regular laminæ are formed, succeeded by acervuline structures. A very fine and regular specimen in my collection has 100 laminæ in a thickness of 3½ inches, giving a little more than a thirtieth of an inch for the average height of each lamina of sarcode and shell-wall.

In order to test the state of preservation of the canal system and nummuline layer, I treated a great number of specimens from different parts of the bed with a dilute acid. The result was, that in all the canal system could be detected in greater or less perfection in the thicker laminæ near the base of the forms, and in some through a great number of the laminæ. The structure of the nummuline layer was not so constantly preserved, its tubuli not being infiltrated in some parts, so that it appears as a structureless band, or fails altogether to be visible. In no instance could it be seen to pass into chrysotile, as recently affirmed by Messrs. Rowney and King*, although chrysotile veins often run very near to or across the walls. The nummuline layer is almost always distinctly limited by parallel surfaces, with its tubes at right angles, or nearly so, to these. The sort of chevron arrangement figured by Rowney and King in fig. 7 of their plate, in the number of the 'Annals of Natural History' for October 1874, I have never observed; and Mr. Weston, who has prepared and examined microscopically hundreds of specimens of *Eozoon*, was struck with the inaccuracy of the representations in this plate, and remarked on it the first time that I met him after he had seen the paper referred to. Figs. 2 and 3, Pl. X., relate to these points, and show the actual nature of the nummuline wall and its relation to the intermediate skeleton and chrysotile veins, as do also the figures recently published by Dr. Carpenter in his paper in the 'Annals'†.

By careful scrutiny of the beds we were enabled to detect two new forms of *Eozoon*, which may eventually prove to be distinct species, but which for the present may be regarded as varietal forms.

One of these, found *in situ* by Mr. Weston, is flat in form and very finely laminated, with thin walls except near the lower part, where there is some supplemental skeleton with finer and more curved canals than usual. The thin walls or laminæ of the ordinary skeleton are connected by very frequent vertical pillars or partitions, and are as numerous as thirty in half an inch, while the whole thickness of the specimen does not exceed an inch. It thus very closely resembles some of the Devonian and Silurian *Stromatoporæ*, especially when seen on the weathered surface. It may be named in the mean time variety *minor*.

The second occurs in more or less oval patches a few inches in diameter, limited by a sort of frame or border of compact serpentine, and presenting under the microscope an aggregation of small acervuline chamberlets, having the proper wall filled with unusually long parallel tubes, and with little development of supplemental or intermediate skeleton. The appearance of parallel tubulation running through and past several successive chamberlets was more conspicuous in these specimens than in the ordinary acervuline *Eozoon*, and the chamberlets themselves more cylindrical and tortuous. These specimens may either be portions of the acervuline superficial part of *Eozoon* broken off and separately preserved, or they may constitute a distinct varietal form. As the latter seems on the whole most probable, I would name this form variety *acervulina*.

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* Ann. & Mag. of Nat. Hist. May 1874.

† *Ibid.* June 1874.

These varieties are of much more rare occurrence than the ordinary type of *Eozoon*.

The ordinary specimens of *Eozoon* found at St. Pierre are mineralized with serpentine; but fragments imbedded in the dolomitic limestones have their canals filled with a transparent mineral which, from its optical character, is evidently dolomite, though the quantity obtained was not sufficient for any definite chemical test. Parts of the canals in these specimens were filled with calcite, as shown by its dissolving entirely away in a dilute acid. In one of the serpentinous specimens also I have observed that, while portions of the groups of canals, especially the basal portions, are filled with serpentine, the extremities of the canals and their finer branches present, under polarized light, the aspect of calcite; and that they are filled with this mineral is proved by these portions of the canal-filling being entirely removed when treated with dilute acid. It would thus appear that in these specimens, while the terminal parts of the canals have been filled with calcite, the basal portions have been occupied by serpentine. This is not, however, a new fact, as similar appearances have been already described both by Dr. Carpenter and the writer.

In one specimen I observed a portion of the fossil entirely replaced by serpentine, the walls of the skeleton being represented by a lighter-coloured serpentine than that filling the chambers, and still retaining traces of the canals. The walls thus replaced by serpentine could be clearly traced into connexion with the portions of those still existing as calcite. This shows that the serpentine, like the quartz in silicified shells and corals, has had the power of replacing the calcite of the fossils; and I believe that its partial action in this way accounts for some irregularities observed in the less perfectly preserved specimens. Nor is it improbable, as Dr. Hunt has already suggested, that some of the masses of serpentine and pyroxene on which specimens of *Eozoon* are based, may represent older and more perfectly mineralized masses of the fossil.

In some of the specimens of *Eozoon*, the superficial laminæ are apparently broken and displaced in such a manner as to suggest the idea that partial disintegration by the waves had taken place before they were finally buried. It is also observable that in some of the masses the compression to which they have been subjected has produced a microscopic faulting, which slightly displaces the laminæ.

One of the most interesting features of the St.-Pierre limestone, not noticed by previous observers, is the occurrence of layers filled with little globose casts of chamberlets, single or attached in groups, and often exactly resembling the casts of *Globigerinæ* in greensand (Pl. X. figs. 4–10). On weathered surfaces they were often especially striking when examined with the lens. In some cases the chamberlets seem to have been merely lined with serpentine, so that they weather into hollow shells. The walls of these chamberlets have had the same tubulated structure as *Eozoon* (fig. 4); so that they are in their essential characters minute acervuline specimens of that species, and similar to those which I described in my paper of 1867* as occurring in the limestones of Long Lake and Wentworth, and also in the loganite filling the chambers of specimens of *Eozoon* from Burgess. Some of them are connected with each other by necks or processes, in the manner of the groups of chamberlets described by Gümbel as occurring in a limestone from Finland, examined by him. That they are organic I cannot doubt, and also that they have been distributed by currents over the surface of the layers along with fragments of *Eozoon*. Whether they are connected with that fossil or are specifically distinct may admit of more doubt. They may be merely minute portions detached from the acervuline surface of *Eozoon*, and possibly of the nature of reproductive buds. On the other hand, they may be distinct organisms growing in the manner of *Globigerina*. As this is at present uncertain, and as it is convenient to have some name for them, I propose to term them *Archæosphærinæ*, understanding by that name minute Foraminiferal organisms, having the form and mode of aggregation of *Globigerina*, but with the proper wall of *Eozoon*.

In slicing one of my specimens from Côte St. Pierre I have recently observed a very interesting peculiarity of structure, which deserves mention. It is an abnormal thickening of the calcareous wall in patches extending across the thickness of four or five lamellæ, the latter becoming slightly bent in approaching the thickened portion. This thickened portion is traversed by regularly placed parallel canals of large size, filled with dolomite, while the intervening calcite presents a very fine dendritic tubulation. The longitudinal axes of the canals lie nearly in the plane of the adjacent laminæ. This structure reminds an observer of the *Cœnostroma* type of *Stromatopora*, and may be either an abnormal growth of *Eozoon*, consequent on some injury, or a parasitic mass of some Stromatoporoid organism finally overgrown by the *Eozoon*. The structure of the dolomite shows that it first incrusted the interior of the canals, and subsequently filled them—an appearance which I have also observed in some of the larger canals filled with serpentine, and which is very instructive as to their true nature.

From the above facts the true nature of *Eozoon* may, I think, be rendered evident to any geologist, however little he may have made the fossil Foraminifera a subject of study. The theories as to its origin may be summed up thus:—

1. The complicated theory of pseudomorphism and replacement,

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* Quart. Journ. Geol. Soc. vol. xxiii. p. 260.

advocated by Messrs. Rowney and King, may be dismissed at once. Independently of the insuperable chemical difficulties which have been pointed out by Dr. Hunt*, and which he proposes to discuss more fully in his papers on Chemical Geology, now in the press, we have the further facts that no replacement of serpentine by calcite is indicated by the relations of these minerals to each other, while such replacement as does occur is in the other direction, or the change of calcite into serpentine, as evidenced by the state of preservation of some specimens of *Eozoon*, above referred to. Further, this theory fails to give any explanation of the specimens mineralized by pyroxene, dolomite, and calcite, or to account for the nummuline wall, except by attributing it to the alteration of chrysotile, which is inadmissible, as the veins of this mineral are newer than the walls supposed to have been derived from them.

2. Inasmuch as many apparently concretionary grains and lenticular masses of serpentine exist in the Laurentian limestones, it may be supposed possible that *Eozoon* is merely a modification of these concretionary forms. In this case, the filling of each lamina and chamberlet of *Eozoon* must be regarded as a separate concretion; and even if we could suppose some special cause to give regularity and uniformity to such concretions in some places and not in others, we still have unaccounted for the canals and tubuli, or the delicate threads of serpentine representing them. Further, we have to suppose that a tendency to this regular and complicated arrangement has affected in the same way minerals so diverse as serpentine, loganite, pyroxene, and dolomite.

3. The only remaining theory is that of infiltration by serpentine of cavities previously existing in the calcite. There is no chemical objection to this, inasmuch as we know of the infiltration of fossils in other formations by minerals akin to serpentine; and in these limestones the veins of fibrous serpentine have evidently been introduced by aqueous action subsequently to the production or fossilization of the *Eozoon*. Further, the white pyroxene of the Laurentian limestones, and the loganite and dolomite, are all known to have been produced by aqueous deposition. The only question remaining is, Whence came the original calcite skeleton with laminæ, chambers, canals, and tubuli to be so infiltrated? The answer is given in the comparison with the tests of Foraminifera, originally proposed by the writer, and illustrated in so conclusive a manner by the researches of Dr. Carpenter.

I may add, in conclusion, that had geologists generally the opportunity of studying *Eozoon in situ*, in good exposures, like that at St. Pierre, they would much more fully understand and appreciate the arguments for its organic nature, than when they have had opportunities of examining only polished specimens and slices†. Its

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* Trans. Royal Irish Academy, 1871.

† I have been sorry to find, from specimens in the cabinets of my friends, that some London dealers are in the habit of circulating specimens labelled "*Eozoon canadense*" which have no trace of the structures of the fossil, but are either badly preserved acervuline portions or merely ordinary serpentine marble. Such specimens can, of course, only mislead, and may produce much unnecessary scepticism.

Stromatoporoid masses, projecting from the weathered beds of limestone, would at once attract the attention of any collector; and the whole conditions of its occurrence, whether entire or in fragments, are precisely those of fossil corals in the Silurian limestones. Further, the symmetry and uniformity of its habit of growth are much more apparent when they can be studied in large specimens prepared by natural weathering or by treatment with an acid.

[*Note* (Oct. 30).—Messrs. Richardson and Weston, of the Geological Survey, have recently revisited the locality of *Eozoon* at Côte St. Pierre mentioned in the above paper, and have collected some additional specimens. One of these deserves notice, as illustrating the nature of *Archæosphærinæ*. It is a small or young small specimen, of a flattened oval form, $2\frac{1}{2}$ inches in its greatest diameter, and of no great thickness (fig. 1). It is a perfect cast in serpentine, and completely weathered out of the matrix, except a small portion of the upper surface, which was covered with limestone which I have carefully removed with a dilute acid. The serpentinous casts of the

Figs. 1–4.—*Small weathered Specimen of* Eozoon *from Petite Nation.*

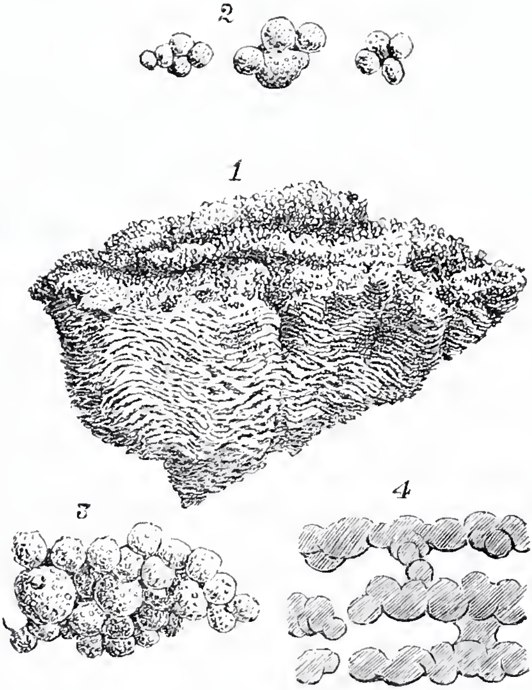

Fig. 1. Natural size; showing general form, and acervuline portion above and laminated portion below.
2. Enlarged casts of cells from upper part.
3. Enlarged casts of cells from the lower part of the acervuline portion.
4. Casts of sarcode layers from the laminated part; enlarged.

chambers are in the lower part regularly laminated; but they are remarkable for their finely mammillated appearance, arising from their division into innumerable connected chamberlets resembling those of *Archæosphærina* (fig. 4). In the upper part the structure becomes acervuline, and the chamberlets rise into irregular prominences, which in the recent state must have been extremely friable, and, if broken up and scattered over the surfaces of beds, would not be distinguishable from the ordinary *Archæosphærinæ*. This specimen thus gives further probability to the view that the *Archæosphærinæ* may be for the most part detached chamberlets of *Eozoon*, perhaps dispersed in a living state and capable of acting as germs.]

EXPLANATION OF PLATE X.

Fig. 1. Fragments of skeleton of *Eozoon*, imbedded in dolomite limestone. (*a*) Fragment with canals. (*b*) Fragments not showing canals. (*c*) Dolomite. (Magnified 10 diameters.)

2. Laminated *Eozoon*, with vein of chrysotile. (*a*) Calcareous wall, slightly eroded with acid. (*b*) Serpentine filling chambers. (*c*) Chrysotile vein crossing the structures. (10 diam.)

3. Portion of a specimens imilar to that in fig. 2; a very thin slice more highly magnified. (*a*) Intermediate skeleton with portions of two large canals. (*a*') Proper wall with fine tubulation. (*b*) Serpentine filling chambers. (*c*) Chrysotile vein traversing serpentine. (Magnified 90 diam.)

4. Small *Archæosphærina*, showing tubulated wall. (200 diam.)

5, 6, 7, 8. *Archæosphærina*, casts, as opaque objects, of some of the varieties. (75 diam.)

9 and 10. Similar specimens seen in section. (75 diam.)

The specimen represented in fig. 4 is from Long Lake; all the others are from Petite Nation.

DISCUSSION.

Prof. DUNCAN said that he thought the author had run the mineralogists rather hard. For his own part, when he first examined specimens of *Eozoon* he had come to the conclusion that they were ancient Foraminifera with Nummuline peculiarities; and since he had acquired a more intimate acquaintance with fibrous minerals and serpentines, he found himself more than ever confirmed in this view. The discovery of isolated masses was very interesting, seeing that, whether they were separated fragments or distinct organisms, they still showed the Nummuline structure. Prof. Duncan compared the habit of growth of *Eozoon* to that of the Nullipores, and suggested that it would be more philosophical to refer both the latter and the Foraminifera to Häckel's group "Protista."

Mr. ETHERIDGE remarked upon the singular fact that whilst, as a general rule, we were disappointed in obtaining instructive sections of *Eozoon*, we had only to go to Dr. Carpenter to see sections which seemed to be convincing. He thought the difference of opinion that prevailed as to the nature of *Eozoon* was due mainly to the difficulty that certainly existed of procuring specimens to show the so-called tubuli and stolons. He stated that he had received from Jersey specimens which at the first glance he said were like

Eozoon; and on getting sections of these made, organic structure at any rate seemed to be present. He had specimens of *Stromatopora* so like *Eozoon* in external appearance, that Sir W. Logan on seeing them immediately mistook them for the latter.

Prof. Ramsay said that he was pleased to find that there might be some relation between *Eozoon* and *Stromatopora*. For his own part he did not see how the structure described as *Eozoon* could have been formed, unless it was of organic origin.

Mr. Evans remarked that, it seemed to him, one of the most interesting points of the paper consisted in the indication (he believed, for the first time) of the occurrence of possibly separate organisms associated with *Eozoon*. They apparently bore a close resemblance to *Globigerina*; and, considering the conditions of fossilization, their presence seemed to confirm the notion of the organic and indeed Foraminiferal origin of *Eozoon*.

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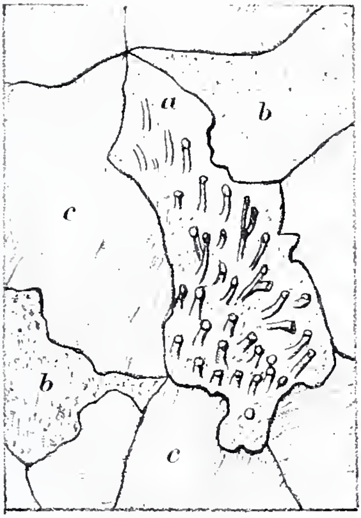

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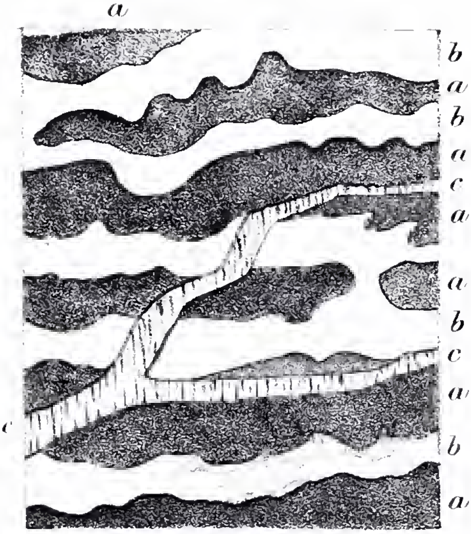

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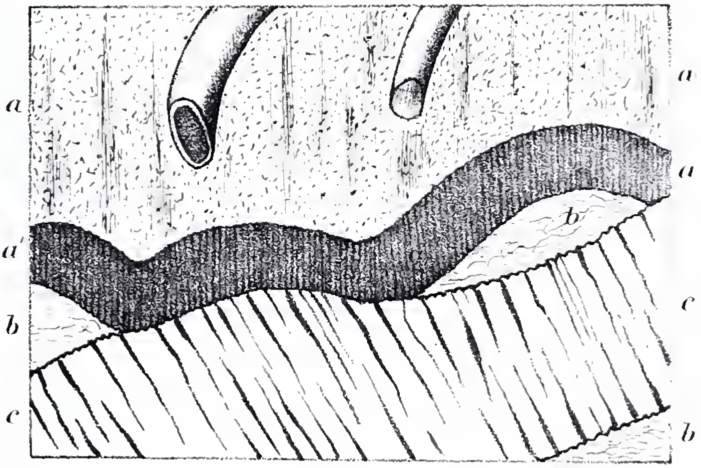

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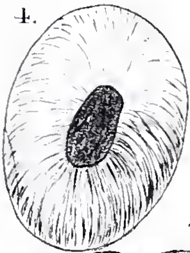

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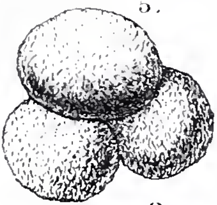

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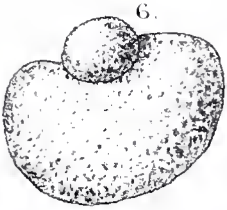

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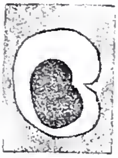

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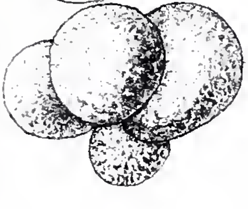

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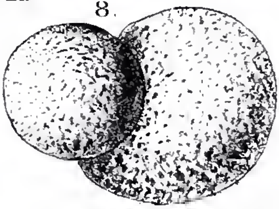

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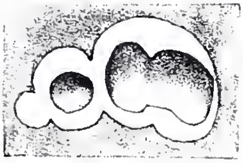

G.H. Ford lith.

Mintern Bros. imp.

EOZOON AND ARCHÆOSPHÆRINÆ.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

MODERN IDEAS OF DERIVATION.

Address of Principal DAWSON, as President of the Natural History Society of Montreal. Read at the Annual Meeting, May 18th, 1869.

The sphere of this Society as a modest collector and preserver of local facts in Natural History, does not preclude its glancing at the more difficult and abstruse questions which agitate Naturalists elsewhere; and perhaps no place is more fitting for this than the annual address of the President. I propose, therefore, on the present occasion, to direct your attention to the present state of those exciting questions agitated in our day by Geologists, Zoologists and Botanists, as to the origin of Species and Genera, and the law of their creation.

Time was when Naturalists were content to take nature as they found it, without any over curious inquiries as to the origin of its several parts, or the changes of which they might be susceptible in time. Geology first removed this pleasant state of repose, by showing that all our present species had a beginning, and were preceded by others, and these again by others. Geologists were, however, too much occupied with the facts of their science to speculate on the ultimate causes of the appearance and disappearance of species, and it remained for Zoologists and Botanists, or as some prefer to call themselves, Biologists, to construct hypotheses or theories to account for the ascertained fact that successive dynasties of species have succeeded each other in time. In our day, Darwin has given to such speculations a form and coherency which they did not before possess, by his doctrine of Natural Selection; and theories of derivation and transformation are perhaps more popular than at any previous time, and are impressing themselves legibly on the practical every day work of science. In these circumstances it becomes necessary to watch the phases of opinion on this subject, to examine the various doctrines propounded, and to ascertain what progress they are making, if any, toward the goal of truth.

A very important contribution to this work has recently been made by Professor Owen in the concluding chapter of his great book on Physiology, just completed; and I shall take this as the basis of some remarks on the present state of the question of derivation.

Prof. Owen, availing himself of the privileges of a father in Science, goes back to 1830 in reviewing the history of doctrines of derivation, and shows that in his student days the question of the origin of species was agitated by the great Cuvier and his contemporary, Geoffroy St. Hilaire, and that both of these great masters of Natural Science had doubts as to the permanency of species in geological time, though neither had before him enough of biological evidence to establish this as a fact, or to frame any certain theory as to the relation of modern to extinct species; and Cuvier, at least, saw evidence against derivation in the apparent want of connecting links between fossil and recent species. Owen endeavours to arrange the questions raised in 1830 under several heads, and to state each as then agitated, and to "post it up," so to speak, to the present period—his evident intention being to show that the views of Darwin and other recent advocates of theories of derivation are by no means so original as they are supposed to be.

The first great question agitated by the French naturalists forty years ago is that grand one — Is there unity of plan or final purpose in living creatures? Are the homologies or resemblances of structure in organized beings merely parts of the general plan, or do they point to genetic or other relations of derivation? Are the beautiful adaptations of organs to functions, and of organisms to places in nature, evidences of deliberate purpose working out its ends by means, or have the external necessities given form to the organs? On this question Cuvier, in his assertion of teleology, evidently took the broader and more philosophical view, that which commends itself to the grander and higher style of mind; but neither he nor his opponent were in a position to see fully the bearings of the question. Owen himself, though largely in advance of most other writers of this time, is not free from misconceptions. He clearly sees, with all the more profound thinkers among naturalists, that whichever view we adopt, the problem can be solved only on the hypothesis of a "predetermining intelligent Will." Without this, nature is only a riddle without a solution—man himself a contradiction and impossibility. But, admitting this, are those resemblances which we call homologies, those adaptations which we call analogies, results of direct creative acts or of the operation of secondary causes? If the former, they are ultimate facts, referable directly to will; if the latter, we may study their more immediate causes, and the laws under which these operate. Cuvier and many of his most illustrious disciples have been content to adopt the former alternative. Owen declares that in this he has been led to differ from his great master. The reasons which he gives under this head are, it must be confessed, feeble. He found it necessary to assume an "archetype" or ideal type in explaining the vertebrate skeleton; but this would have been equally suitable under the hypothesis of direct creation or that of secondary causes. He saw in the recurrence of similar segments in a vertebral column and other cases of repetition of similar parts, something analogous to the repetition of similar crystals, as the result of "polarizing force in the growth of an inorganic body." But there is scarcely more philosophy in this than there is in the process by which a savage, ignorant of manufacturing processes, might explain, as the result of some unknown process of crystallization, the recurrence of forms in the pattern of a piece of calico or in the beads of a necklace. Still we are willing to allow due value even to the impressions made upon the minds of naturalists by such facts, and to go on to the next question of the series. Before doing so, however, we must take exception to one expression of the great English naturalist, which, in various forms, recurs in several places. He calls the theory of derivation a principle "more especially antagonistic to the theological idea" of creation. Now, if by the theological idea he means that promulgated in the first chapter of Genesis, he should explain wherein the antagonism consists. The object of the writer in Genesis is obviously to illustrate and enforce the existence and attributes of the Supreme Intelligent Will as opposed to Polytheism, Pantheism and Atheism, and the fact of an orderly and serial origin of things. But if he says that animals were made "according to their kinds," has any modern naturalist a right to hold that the kinds or species of Genesis are equivalent to those of any school of zoologists in our day? Further, all who profess to be acquainted with this part of theology should know that the word "create" is applied in Genesis only to the first animals, and to man considered as an intelligent and moral agent. The other animals and all plants are said to have been "made," "formed," "brought forth," implying that the writer had before his mind the idea of a primary and secondary kind of origin of organized beings. I endeavoured many years ago, in a work well known to members of this Society, and published before Darwin's Origin of Species, to illustrate this old "theological idea." Since naturalists will bring up such subjects, I may be excused for reminding them that if they should come to believe, on zoological and geological grounds, that some of the entities which we call species have been produced by a method which may be properly termed creation, and others by secondary processes, they may possibly find themselves to be in perfect harmony with the oldest and most authoritative theological ideas on the subject.

The second great question as to Derivation is that which relates to the succession of species in Geological time. Was this broken or uninterrupted? Did new species die out and were old ones created in their room, or were the new ones derived by some secondary process from those which preceded them? This question can only be finally settled by inductive investigation, and unfortunately our knowledge of extinct animals and plants is still too imperfect to give us the necessary accumulation of facts. We can only inquire as to a few cases a little better known to us than others. One curious feature of the inquiry is that it seems easier to show relationships between large groups of animals than between particular species. The reasons of this will appear farther on. Prof. Huxley, with his usual dexterity in presenting these problems to the popular comprehension, has recently taken advantage of this in tracing the links of connection between birds and reptiles.* By a series of cleverly arranged transitions, he has succeeded in constructing such a series as no doubt sufficed to convince many of his auditors that the gigantic and grotesque Iguanodons of the Mesozoic rocks might have been the progenitors, if not of wrens and titmice, at least of ostriches and cormorants. Yet he could not have placed together any two members of the supposed series without convincing any naturalist that an enormous gap had to be filled between them. Prof. Owen, writing to naturalists, does not attempt this sort of intellectual sleight of hand, but presents, as a case in point, the supposed progenitors of the horse. That useful quadruped was preceded in the tertiary period (Miocene and Pliocene) by a horse-like animal, the Hipparion, which, among other things, differed from its modern representative in having its splint bones represented by two side toes, a conformation supposed to adapt it to locomotion on soft and swampy ground. The Hipparion was preceded in the earlier tertiary (Eocene) by the Palæotherium, in which the side toes were still further developed so as to touch the ground, giving the foot a tridactyle character. These relations induce Owen to believe that these forms may be an actual genetic series, the species of Palæotherium passing through a succession of changes into the modern horse. Perhaps this case, as put by Prof. Owen, affords as fair an example as we can obtain of the bearing of a derivative hypothesis. The three genera in question are closely allied. They succeed each other regularly in Geological time. The horse shows in his splint bones rudiments of organs, which, serving little apparent purpose in him, were more fully developed and of manifest use in his predecessors. Modern horses have occasionally shown a tendency to develop the side toes, as if returning to the primitive type. Taking this as a fair example of derivation, and admitting, for the sake of argument, its probability, let us consider shortly some of the questions that may be raised with regard to it. These are principally two.

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* Royal Institution Lecture on Animals intermediate between Birds and Reptiles.

1. What limits, if any, must necessarily be set to such an hypothesis, and what relations does it bear to the origin of life at first and to the succession of animals in Geological time?

2. What causes may be supposed to have led to such derivation?

Under the first head, we have to enquire as to the limits set to derivation by the structure of organic beings themselves, and by the physical conditions and changes which may affect them. It will be convenient to consider these together.

Supposing that Palæotherium, Hipparion and Equus are links in a chain extending from the Eocene Tertiary to the present time, can we suppose that by tracing the same series further back it might include any Mammal. We must answer decidedly not, for if the whole time from the Eocene to the present has been required to produce the comparatively small change required from Palæotherium to horse, that in other cases would carry us back to the Mesozoic period, long before we have any evidence of the existence of "placental mammals." In other words, the Tertiary and Modern Periods will give us time enough only to effect changes of Mammals within the order Pachydermata, and perhaps in only one section of that order. The other orders must therefore constitute separate series, and these series must have been advancing abreast of each other. Had each series a separate origin, or is there any Mammalian stock in the Mesozoic from which, at the beginning of the Tertiary, these several lines of types may have diverged? Here our information fails. We know only a few small Marsupial Mammals in the Mesozoic. On our hypothesis it is possible that these may have been the progenitors of the more varied and advanced Marsupials of the Tertiary and Modern periods, but scarcely of the placental Mammals of the Eocene. There may have been placental Mammals, unknown to us, in the Mesozoic, which may constitute the required stock. The reptiles of the Mesozoic utterly fail to give us the necessary links. If they were changing into anything it was into birds, not into Mammals.

Again, the time in which the horse and its supposed progenitors have lived is one of continuous, unbroken succession of species. More especially in the later Tertiary there seems the best evidence of gradual extinction and introduction of species, without any very wide-spread and wholesale destruction, and this notwithstanding the intervention of that period of cold and of submergence of land in the Northern hemisphere, which has given rise to all the much-agitated glacial theories of our time. Can we affirm that such piecemeal work has continued throughout Geological time? At this point opens the battle between the Catastrophists and Uniformitarians in Geology, a battle which I am not about to fight over again here. I have elsewhere stated reasons for the belief that neither view can be maintained without the other, and that Geological time has consisted of alternations of long periods of physical repose and slow subsidence in which our more important fossiliferous formations have been deposited, with others of physical disturbance and elevation, with extinction of species. Dana has well shown how completely this view is established by the series of Geological formations as seen on the broad area of the American continent. Now the question arises, how would the law of derivation operate in these two different states of our planet? Let us suppose a state of things in which far more forms were being destroyed than were reproduced—another in which introduction of species was more rapid than extinction. In the latter case we may suppose an exuberance of new species to have been produced. In the former there would be a great clearance of these, and perhaps only a few types left to begin new series. Do we now live in one of the periods of diminution or of increase? Perhaps in the former, since there seems to have been, in the case of the Mammalia of the Post-pliocene, an enormous amount of extinction of the grandest forms of life, apparently without their replacement by new forms. If so, how far can we judge from our own time of those which preceded it? They may have been far more fertile in new forms, or perhaps farther in excess in the work of extinction. The question is further complicated with that which asks if these differences arise from merely physical agencies acting on organic beings from without, or is there in the organic world itself some grand law of cyles independent of external influences? The answers to such questions are being slowly and laboriously worked out by Geologists and Naturalists, and all the more slowly that so many inevitable errors occur as to the specific or varietal value of fossils and the relative importance of Geological facts, while the great gaps in the monumental history are only little by little being filled up.

Nothing can more forcibly illustrate the amount of work remaining to be done toward the settlement of these questions than a glance at the elaborate and most valuable "Thesaurus Siluricus" of Dr. Bigsby, recording, as it does, nearly 9,000 species of animals already found in the Silurian rocks. The rapid increase in the number of known species shows that we know as yet but a fraction of this ancient fauna, while the facts relating to introduction, extinction, geographical distribution and distribution in time, show that we are still a very long way from any definite conclusions as to the general law of succession and its relations to physical changes.

The application of these questions to the animals referred to by Owen, will serve farther to shew their significance as to limitations of derivation. Pictet catalogues eleven species of Eocene Palæotheria. Without inquiry as to the origin of these, let us confine ourselves to their progress. Under the hypothesis of derivation, each of these had capacities for improvement, probably all leading to that line of change ending in the production of the horse. If so, then each of our Palæotheria, passing through intermediate changes, may be the predecessor of some of the equine animals of the Post-pliocene and Modern periods. But if, as seems probable, the time intervening between the Eocene and the Modern was unfavourable to the multiplication of such species, then several may have perished utterly in the process, and all might have perished. Supposing, on the contrary, the time to have been favourable to the increase of such creatures, we might have had hundreds of species of equine animals instead of the small number extant at present. Again, what possibilities of change remain in the horse? Can he be supposed capable of going on still farther in the direction of his progress from Palæotherium, or has he attained a point at which further change is impossible? Will he then, in process of time, wheel round in his orbit and return to the point from which he set out? Or will he continue unchanged until he becomes extinct? Or can he at a certain point diverge into a new series of changes? We do not know any Palæotherium before the Eocene. Is it not possible that they may have originated in some way different from that slow change by which they are supposed to have been transmuted into horses, and that in their first origin they were more plastic than after many changes had happened to them? May it not be that the origin of forms or types is after all something different from derivative changes, and that new forms are at first plastic, afterwards comparatively fixed—at first fertile in derivative species, and afterward comparatively barren. Certainly, unless something of this kind is the case, we fail to find in the Modern world a sufficient number of representatives of the Palæotheria, Anoplotheria, Lophiodons, Elephants and Mastodons of the tertiary. On the other hand, it is scarcely possible to find a sufficient starting point in the

Eocene for the multitude of Ruminants and Carnivores and Quadrumana of the Modern time.

But it may be said, and truly, that these higher forms of life put the doctrine of derivation to the severest test. If we take marine invertebrata, we may trace analogues of these back into the earliest geological periods, and as the species are very numerous, and their structures more simple, it is easier to imagine a continuous derivation with respect to them. Still, even here such facts as the vast multiplication of species of Trilobites, Ammonites, Belemnites, and Ganoid Fishes, at different periods of Geological time, and their disappearance without modified successors, point to limitations of any law of derivation that may be suggested.

To sum up where all is so uncertain is not easy; but we may, I think, affirm that if existing animals are derivative as modified descendants of others—(1) They belong to a vast number of lines of modification which would require to be traced backward separately. (2) That many of these lines end abruptly in comparatively recent periods, perhaps in consequence of our defective information, perhaps because of some other law of creation. (3) That in some periods a series must suddenly bud forth into many ramifications, and in others contract to a few representations or be altogether dropped. (4) That the beginning of such series may take place in a different manner from derivation, and that the law of new series is probably different from that of those of longer derivation. (5) That it is absurd to suppose that any modern animal has originated from any now contemporary with it (e.g., man from the gorilla or bears from seals), since all these existing species must belong to series to be traced backward through species now extinct, and possibly unknown to us. (6) That while it is obvious that such derivation must be related to contemporary physical changes, our views of the nature of that relation must depend on those which we take of the causes of derivation itself.

Before proceeding farther we may remove another of the "theological" misconceptions under which Owen and some other writers on this subject seem to labour. They think that the "Biblical flood" interposes some difficulties in the way of their speculations as to the origin of species. They may readily be relieved from all embarrassment on this subject. The language of the Noachian record in Genesis implies that the Deluge was universal only in so far as man was concerned. The catalogue of animals taken into the Ark, five times repeated, and that of animals destroyed, twice given, show that only a very limited number of species were in the Ark, and that of the rest some certainly survived—others may have perished. Farther, the catastrophe does not require us to suppose either that coral polypes and other marine animals were overwhelmed with fresh water or under an abyssal depth of ocean, for the submergence of the dry land, or of a portion of it, by the "breaking up of the fountains of the great deep," does not imply a deepening of the ocean, but possibly to some small extent a shallowing of it. If the Royal Institution, of London, which has recently done so much in its courses of lectures to ventilate new and sometimes questionable scientific hypotheses, would employ some one to give a few exegetical lectures on the earlier chapters of Genesis, without entering into any disputed questions of criticism, but merely explaining the literal meaning of the terms of the record, it would confer an inestimable benefit on those Naturalists who seem to have derived their notions of the Biblical Creation and Deluge from the picture books and toy Noah's Arks of their childhood, with the comments of their nursery-maids thereon.

It still remains to us to inquire whether the doctrine of derivation can throw any light on the origin of life at first. Nothing in the doctrine of derivation itself necessitates the belief that change has always been in the direction of improvement or of increased complexity; but the Geological history of the earth and the succession of fossils lead to the belief that the general tendency of creation has been from more generalized to more specialized forms, and from simpler to more complex organisms. Still, it is evident that this general doctrine of improvement is to be held with some limitations of detail. For example, the very lowest forms of life have continued down to the present, and some of them—for instance, the sponges and Foraminifera—have apparently attained to their greatest extension in number of species in comparatively late periods. Further, every new form when first introduced appears to be at its maximum in point of development; or, if not so, it rapidly attains to this, and again deteriorates when being supplanted by other and newer forms. Numerous examples of this will occur to every Geologist. Admitting, however, that development has in some cases been indefinitely postponed, and that in others it has advanced by successive waves, each retreating before the advance of the next, still, we may hold that it would be fair to assume a gradual progress from lower to higher forms. Assuming this, and that the lower have preceded the higher, we may limit our inquiry as to the origin of life to the lowest forms, and ask what is involved in the question of their origin. Now, it is easy to affirm that the lowest animals and the lowest plants are but Protoplasm, which is only another name for the chemical compound Albumen, and that if we can conceive this to originate from the inorganic union of its elements, we shall have a low form of life from which we can deduce all the higher forms of vital action. In making such affirmation we must take for granted several things, none of which we can yet prove :—(1) That vital force is merely a modification of some of the forces acting in unorganized matter ; (2) That such force can be spontaneously originated from other forces without the previous existence of organization ; (3) That being originated, it has the power to form Albumen and other organic compounds. Or, if we prefer another alternative, we may take, instead of the last statement, :—(1) That Albuminous matter can be produced by the union of its chemical elements without life or organization ; (2) That being so produced it can develop vital forces and organization, including such phenomena as sensation, volition, reproduction, &c. To believe either of these doctrines in the present state of science is simply an act of faith, not of that kind which is based on testimony or evidence, however slight, but of that unreasoning kind which we usually stigmatize as mere credulity and superstition. It will not help us here to say that vegetable and animal infusions, destitute of germs, will produce a "mucous layer" or "proligerous pellicle" from which organisms may arise, for in the first place such infusion itself contains organic matter, and, as Tyndall has lately shown incidentally in his experiments with the electric light, we have to operate with air and water and vessels, which it is wholly impossible by any chemical or mechanical process to free completely from the smaller kinds of germinal matter.

It is rather discouraging thus to find that, on the philosophy of derivation, as our faith advances the demands upon it increase, until, from belief in the derivation of Horses from Hipparia, we are finally obliged to believe that life with all that it involves is nothing but a peculiar manifestation of dead inorganic forces. In order that, if possible, we may relieve ourselves from this burden, let us now turn to our second inquiry, and consider the causes which are alleged to produce the transmutation of species.

Leaving out of the account many fanciful and untenable hypotheses, both ancient and modern, we may notice:—(1) The Lamarckian theory of Appetency; (2) The Darwinian theory of Natural Selection; (3) The Owenian doctrine of "Innate tendency to deviate from parental type;" (4) The doctrine of arrested or advanced embryonic development;—with the view of ascertaining how far these several hypotheses may be employed to account for observed facts.

(1.) The Lamarckian theory is essentially that of effort in certain directions giving power in those directions, and consequently altering organs. That it has a real basis in nature no one can doubt who has observed the effect of use and effort in determining the development of organs. That it can produce only varietal forms and not species, and that it is practically very limited in its operation, are facts equally patent. It is a mistake, however, to suppose that Lamarck confined himself to the effect of will in producing change. He considered also the effect of external circumstances, and of habits induced by such circumstances, in which respect his theory differed less than is generally supposed from that of Mr. Darwin. The main difference is, that Lamarck supposed animals to be acted on by an attractive influence from before, Darwin by a propelling influence from behind. In this respect Lamarck's hypothesis is the more philosophical, when regarded as means of real progress; but it is less applicable to the lower animals and to plants than to animals of high grade.

(2.) The most popular theory of derivation in the present day is undoubtedly that of Darwin. This view is, essentially, that all organized beings are engaged in a struggle for existence; that in this struggle certain varieties arise, which, being more suited to the conditions, prosper and multiply more than others; that this amounts to a "Natural Selection" similar in kind to the artificial selection of breeders of stock; that members of the same species, isolated from each other and subjected to struggles of different kinds, will in process of time become specifically distinct. The difficulties of Darwinism are many. The following may be stated as fatal to it in its capacity of a sole mode of accounting for derivation: — (1) Conditions which involve a struggle for existence are found by experience to result in deterioration and final extinction rather than improvement, and are directly opposite to those employed by breeders for their purposes. (2) Even if we include, along with the struggle for existence, the action of all conditions, favourable and unfavourable, tending to change, we fail to find any evidence of this other than the formation of varieties and races. True species, no longer capable of interbreeding, have not been observed to be produced. (3) Though it is conceivable that species may have been produced during the lapse of time, yet even this is rendered improbable by the enormously long periods which Mr. Darwin himself admits to be necessary, and which seem to overgo the possibility of the existence of the creatures in question as far back in geological time as the theory demands.

(3.) Owen desires to substitute for the above views "an innate tendency to deviate from the parental type operating through periods of adequate duration." According to this hypothesis "a change takes place first in the structure of the animal, and this when sufficiently advanced may lead to modifications of habits." It is difficult to understand this as anything more than a mere statement of a belief in derivation as a fact. It seems to mean that species change because they tend to change. We may add to this if we please that they change independently of external circumstances, and by virtue of a creative plan embodied in them, or rather in the matter of which they are composed; for Prof. Owen appears to stretch his theory so far as to assert the formation of species spontaneously from inorganic matter, thus giving us the additional thesis that species tend to be before they actually exist. It is also to be observed that the tendency to change, though not caused by external circumstances must act in unison with physical changes, otherwise it would be worse than useless. Taking the case of the Hipparion and horse, Lamarck would inform us that the former endeavoured to accommodate itself to drier and harder ground, and thus changed the character of its feet. Darwin would say that as the ground became harder those individuals which had the most equine feet would succeed best in the struggle for existence. Owen very properly demurs to both views, holding that there were dry and wet places suitable for horses and Hipparia both in the Miocene and Modern periods, and that the increase of dry ground would merely limit the range of Hipparia and not produce horses; but he holds that the Hipparia changed into horses merely because they tended to do so, and that if the change suited the conditions of the case, that was a correlation arising from the plans of the Creator, and with which their poor brains and greater or less safety and comfort had nothing to do. If we were disposed to accept this hypothesis of Owen, we should not in doing so arrive at any true cause, and we should at the same time find ourselves involved in the old difficulties. That a Hipparion should change into a horse it would be necessary that not only his feet but his teeth and other structures should change in harmony with each other. This must take place either at once or gradually. If at once, then a pair of horses must be born from Hipparia in one herd, and must be isolated from the rest so as to produce a herd of horses. This is hard to believe; and if we resort to gradual change, the required isolation of the breed will be still more difficult to secure. The demands upon our faith are obviously greater here than even in the hypothesis of Darwin,—that is if we can be induced to place any reliance on the argument of the latter as to struggle for existence.

(4.) The last of these hypotheses which I shall notice, and, in my view, the most promising of them all, is one which has recently been ably advocated by Mr. Edward D. Cope in a memoir on the "Origin of Genera," published in the Proceedings of the Academy of Natural Sciences,* and which is based on the well-known analogy between embryonic changes, rank in the Zoological scale and Geological succession. It may be illustrated by the remarkable and somewhat startling fact, that while no authenticated case exists of animals changing from one species to another, they are known to change from one genus or family to another, and this without losing their individuality. Prof. Dumeril, of Paris, and Prof. Marsh, of New Haven, have recently directed attention to the fact that species of *Siredon*, reptiles of the Lakes of the Rocky Mountains and of Mexico, and which, like our North American *Menobranchus*, retain their gills during life, when kept in captivity in a warmer temperature than that which is natural to them, lose their gills, and pass into a form hitherto regarded as of a different genus and family,—the genus *Amblysoma*. In this case we may either suppose that the Amblysoma, under unfavourable circumstances, has its maturity and reproduction prematurely induced before it has lost its gills, or that the Siredon has, under certain circumstances, the capacity to have its period of reproduction arrested until it has gone on a stage further in growth and has lost its gills. In any case the same species—nay, the same individual—is capable of existing in a state of maturity as a creature half fish and half reptile in regard to its circulation, or in a more perfect reptilian state in which it breathes solely by lungs. Further, we may suppose conditions of the earth's surface in which there would only be Siredons or only Amblysomas, and a change in these conditions inducing the opposite state. Here we have for the first time actual facts on which to base a theory of development. These facts point to the operation of two causes—first, the possible *Retardation* or *Acceleration* of development, and secondly, the action of outward circumstances on the organism capable of this retardation or acceleration. We here substitute for the tendency to vary of Owen's theory, the ascertained fact of reproductive retardation or acceleration, and for the struggle for existence, the action of changed physical conditions, and for the question as to the change of one species into another, the change of the same species from one genus into another. Further, instead of vague speculations as to possible changes of allied animals, we are led to careful consideration of the embryonic changes of the individual animal, and as to the differences that would obtain were its development accelerated or retarded. We can thus range animals in genetic series within which anatomical characters would show change to be possible. I cannot follow these series out into the elaborate lists tabulated by Mr. Cope, but may proceed to notice the limitations which his views put to the doctrine of derivation. It is obvious that, if this be the real nature of derivation as a possible hypothesis, then derivation must follow the same law with metamorphism and embryonic development. Those animals which undergo a metamorphosis must be those most liable to such changes; for example, a Batrachian would be more likely to be so than a true reptile,—consequently those lower forms of animals in which metamorphosis is most decided would be those in which derivation would be most active, and when they had attained to a condition in which metamorphosis is of less amount, the tendency to change would be diminished. When we compare this with the actual succession of animals in geological time, we can see, as many Palæontologists have remarked, that order of succession in time and order of embryonic development correspond with one another to a remarkable degree. We see also, however, that in the higher animals changes of species have taken place more rapidly than in those of lower grade, though in the latter metamorphosis is usually more marked—a fact not apparently in accordance with our hypothesis.

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* Philadelphia, 1869.

According to this view, also, a species once created may have in itself a capacity for passing through several generic forms, constituting a cycle which ever tends to return into itself, or to advance and recede by steps more or less abrupt under the law of retardation and acceleration, combined with the influence of external circumstances. Yet the dimensions of the orbit of each species must be limited, its duration in time must also be limited, and its capacity to pass into a really new species must still be a point subject to doubt, but open to anatomical investigation and inference. As already hinted, it is a most important point of this theory, that when we have ascertained the series of embryonic changes of any animal, we have thereby ascertained its possibilities in regard to accelerated development. Its possibilities in regard to retarded development may be inferred by similar studies of animals higher in the scale. Now, if we knew the embryonic history of every animal recent and fossil, in its anatomical details, we should be able to construct out of this a table of possible affiliation of animals, and should be able to trace our existing species through the same genera, families, orders and classes in which they might have existed in geological time, and to predict what they might become in time still to come. This hypothetical scheme of creation would approach to the actual one in as far as we were able to correlate it with the physical changes which have occurred or will occur on our planet. Let us take as a crucial test the case of man himself. The actual anatomical and physiological differences which obtain between those races in which maturity is latest, and those in which it is earliest, and a comparison of these with embryonic characters, would give us the modern data. The comparison of these with the most ancient human remains might enable us to infer whether retardation or acceleration has been the tendency in historic or geological time. From this we might infer what might be the condition of man under a still more accelerated development than any now known, or under that antediluvian condition in which immaturity is said to have been protracted over half a century, or that still future time predicted in Holy Writ when the days of a man shall be as those of a tree. Having worked out these problems, we would be in a position to inquire as to the possible transition of Homo from or towards any other generic form. I would by no means put forward this theory of embryonic development as including the whole law of introduction of species or genera* any more than the others reviewed, but I must say that to my mind it appears to hold forth the most promising line of investigation, with the hope of arriving ultimately at some true expression of the law of creation with reference to organized beings.

What that law will ultimately prove to be, and to what extent it may include processes of derivation, it is impossible now to say. At present we must recognize in the prevailing theories on the subject merely the natural tendency of the human mind to grasp the whole mass of the unknown under some grand general hypothesis, which, though perhaps little else than a figure of speech, satisfies for the moment. We are dealing with the origin of species precisely as the Alchemists did with Chemistry, and as the Diluvialists and Neptunists did with Geology; but the hypotheses of to-day may be the parents of investigations which will become real science to-morrow. In the meantime it is safe to affirm that whatever amount of truth there may be in the several hypotheses which have engaged our attention, there is a creative force above and beyond them, and to the threshold of which we shall inevitably be brought after all their capabilities have been exhausted by rigid investigation of facts. It is also consolatory to know that species, in so far as the Modern period, or any one past Geological period may be concerned, are so fixed that for all practical purposes they may be regarded as unchanging. They are to us what the planets in their orbits are to the Astronomer, and speculations as to origin of species are merely our nebular hypotheses as to the possible origin of worlds and systems.

One word in conclusion with reference to our own work here as a Society, and as individual collectors of facts. We may not be in a position to take any leading place in the agitation of the questions to which I have referred; but we are well situated for the useful task of accumulating the necessary data for their settlement. The broad area of the American continent, the wide space occupied by its geological formations, the completeness of the series of its palæozoic rocks, the unbroken connection of its post-pliocene and modern fauna and flora, the meeting on this continent within recent times of multitudes of indigenous and exotic species of plants and animals, the existence up to our own time of feral and aboriginal conditions which are pre-historic in the Eastern continent,—these are all points of vantage on which we can seize in dealing with these questions; and if we properly inform ourselves as to what is being done elsewhere, and diligently improve our own opportunities, I see nothing to prevent us from taking the lead of those who in the Old World are pursuing such inquiries in a comparatively narrow field, and under conditions in many respects less favourable. I must insist, however, that this is not to be done by vieing with them in crude speculations and hypotheses, or in building up specious fabrics of conjecture to dazzle the popular eye, but in patient, honest, and careful accumulation of facts.

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* It is but fair to say that Mr. Cope himself admits the action of natural selection as one cause of change.

We should also bear in mind that in the greater centres of literary and scientific life, there is a strong temptation, especially on the part of ambitious men who have their own fortunes to build up, to deal in that sensation science with which the popular literature of the day is deluged. In our own comparatively obscure field there is little inducement to this or opportunity for its display, and this is so far in favor of a healthy scientific tone, which we should endeavour to preserve and cultivate. Our danger arises from being too ready to follow the extreme views put forth elsewhere, and from impatience with the slow returns for honest and careful work.

[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for August* 1871.]

On new TREE FERNS *and other* FOSSILS *from the* DEVONIAN.

By J. W. DAWSON, LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal.

[PLATE XII.]

OF the numerous ferns now known in the Middle and Upper Devonian of North America, a great number are small and delicate species, which were probably herbaceous; but there are other species which may have been tree ferns. Little definite information, however, has, until recently, been obtained with regard to their habit of growth.

The only species known to me in the Devonian of Europe is the *Caulopteris Peachii* of Salter, figured in the Quarterly Journal of the Geological Society for 1858. The original specimen of this I had an opportunity of seeing in London, through the kindness of Mr. Etheridge, and have no doubt that it is the stem of a small arborescent fern, allied to the genus *Caulopteris* of the Coal-formation.

In my paper on the Devonian of Eastern America (Quart. Journ. Geol. Society, 1862) I mentioned a plant found by Mr. Richardson at Perry, as possibly a species of *Megaphyton*, using that term to denote those stems of tree ferns which have the leaf-scars in two vertical series; but the specimen was obscure, and I have not yet obtained any other.

More recently, in 1869, Prof. Hall placed in my hands an interesting collection from Gilboa, New York, and Madison County, New York, including two trunks surrounded by aerial roots, which I have described as *Psaronius textilis* and *P. erianus* in my 'Revision of the Devonian Flora,' now in the hands of the Royal Society*. In the same collection were two very large petioles, *Rhachiopteris gigantea* and *R. palmata*, which I have suggested may have belonged to tree ferns.

My determination of the species of *Psaronius*, above mentioned, has recently been completely confirmed by the discovery on the part of Mr. Lockwood, of Gilboa, of the upper part of one of these stems, with its leaf-scars preserved and petioles attached, and also by some remarkable specimens obtained by Prof. Newberry, of New York, from the Corniferous Limestone of Ohio, which indicate the existence there of three species of tree ferns, one of them with aerial roots similar to those of the Gilboa specimens. The whole of these specimens Dr. Newberry has kindly allowed me to examine, and has permitted me to describe the Gilboa specimen, as connected with those which I formerly studied in Prof. Hall's collections. The specimens from Ohio he has himself named, but allows me to notice them here by way of comparison with the others. I shall add some notes on specimens found with the Gilboa ferns, and on a remarkable plant from the Devonian of Caithness, kindly placed in my hands by Dr. Wyville Thomson.

It may be further observed that the Gilboa specimens are from a bed containing erect stumps of tree ferns, in the Chemung group of the Upper Devonian, while those from Ohio are from a marine limestone, belonging to the lower part of the Middle Devonian.

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* Abstract in Proceedings of Royal Society, May 1870.

1. Caulopteris Lockwoodi, n. sp.

(Plate XII. figs. 1 to 3.)

Trunk from two to three inches in diameter, rugose longitudinally. Leaf-scars broad, rounded above, and radiatingly rugose, with an irregular scar below, arranged spirally in about five ranks; vascular bundles not distinctly preserved. Petioles slender, much expanded at the base, dividing at first in a pinnate manner, and afterwards dichotomously. Ultimate pinnæ with remains of numerous, apparently narrow pinnules.

This stem is probably the upper part of one or other of the species of *Psaronius* found in the same bed (*P. erianus*, Dawson, MS., and *P. textilis*, Dawson, MS. *). It appears to have been an erect stem imbedded *in situ* in sandstone, and preserved as a cast. The stem is small, being only two inches, or a little more, in diameter. It is coarsely wrinkled longitudinally, and covered with large leaf-scars (fig. 2) each an inch in diameter, of a horseshoe-shape. The petioles, five of which remain, separate from these scars with a distinct articulation, except at one point near the base, where probably a bundle or bundles of vessels passed into the petiole. They retain their form at the attachment to the stem, but a little distance from it they are flattened. They are inflated at the base, and somewhat rapidly diminish in size. The leaf-scars vary in form, and are not very distinct, but they appear to present a semicircular row of pits above, largest in the middle. From these there proceed downward a series of irregular furrows, converging to a second and more obscure semicircle of pits, within or below which is the irregular scar or break above referred to. The attitude and form of the petioles will be seen from fig. 1.

The petioles are broken off within a few inches of the stem; but other fragments found in the same beds appear to show their continuation, and some remains of their foliage. One specimen shows a series of processes at the sides, which seem to be the remains of small pinnæ, or possibly of spines on the margin of the petiole. Other fragments show the division of the frond, at first in a pinnate manner, and subsequently by bifurcation; and some fragments show remains of pinnules, possibly of fertile pinnules. These are very indistinct, but would seem to show that the plant approached, in the form of its fronds and the arrangement of its fructification, to the Cyclopterids of the subgenus *Aneimites*, one of which (*Aneimites acadica*), from the Lower Carboniferous of Nova Scotia, I have elsewhere described as probably a tree fern †. The fronds were evidently different from those of *Archæo-*

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* Memoir on Devonian Flora, Proceedings of Royal Society, May 1870.

† Quart. Journ. Geol. Society, 1860.

pteris *, a genus characteristic of the same beds, but of very different habit of growth. This accords with the fact that there is in Prof. Hall's collection a mass of fronds of *Cyclopteris* (*Archæopteris*) *Jacksoni*, so arranged as to make it probable that the plant was an herbaceous fern, producing tufts of fronds on short stems in the ordinary way. The obscurity of the leaf-scars may render it doubtful whether the plant above described should be placed in the genus *Caulopteris* or in *Stemmatopteris*; but it appears most nearly allied to the former. The genus is at present of course a provisional one; but I think it only justice to the diligent and successful labours of Mr. Lockwood to name this curious and interesting fossil *Caulopteris Lockwoodi*.

I have elsewhere remarked on the fact that trunks, and petioles, and pinnules of ferns are curiously dissociated in the Devonian beds—an effect of water-sorting, characteristic of a period in which the conditions of deposition were so varied. Another example of this is, that in the sandstones of Gaspé Bay, which have not as yet afforded any example of fronds of ferns, there are compressed trunks, which Mr. Lockwood's specimens allow me at least to conjecture may have belonged to tree ferns, although none of them are sufficiently perfect for description.

Mr. Lockwood's collection includes specimens of *Psaronius textilis*; and in addition to these there are remains of erect stems somewhat different in character, yet possibly belonging to the higher parts of the same species of tree fern. One of these is a stem crushed in such a manner that it does not exhibit its form with any distinctness, but surrounded by smooth cylindrical roots, radiating from it in bundles, proceeding at first horizontally, and then curving downward, and sometimes terminating in rounded ends. They resemble in form and size the aerial roots of *Psaronius erianus*; and I believe them to be similar roots from a higher part of the stem, and some of them young and not prolonged sufficiently far to reach the ground. This specimen would thus represent the stem of *P. erianus* at a higher level than those previously found. My idea of the possible connexion of these fragments is represented in fig. 3. Mr. Lockwood's collections also contain a specimen of the large fern-petiole which I have named *Rhachiopteris punctata*. My original specimen was obtained by Prof. Hall from the same horizon in New York. That of Mr. Lockwood is of larger size, but retains no remains of the frond. It must have belonged to a species quite distinct from *Caulopteris Lockwoodi*, but which may, like it, have been a tree fern.

2. CAULOPTERIS ANTIQUA, Newberry.

(Plate XII. fig. 4.)

This is a flattened stem, on a slab of limestone, containing Brachiopods, Trilobites, &c. of the Corniferous Limestone. It is about

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* The genus to which the well-known *Cyclopteris* (*Adiantites*) *hibernicus* of the Devonian of Ireland belongs.

18 inches in length, and $3\frac{1}{2}$ inches in average breadth. The exposed side shows about twenty-two large leaf-scars arranged spirally. Each leaf, where broken off, has left a rough fracture; and above this is a semicircular impression of the petiole against the stem, which, as well as the surface of the bases of the petioles, is longitudinally striated or tuberculated. The structures are not preserved, but merely the outer epidermis, as a coaly film. The stem altogether much resembles *Caulopteris Peachii*, but is of larger size. It differs from *C. Lockwoodi* in the more elongated leaf-bases, and in the leaves being more remotely placed; but it is evidently of the same general character with that species.

3. CAULOPTERIS (PROTOPTERIS) PEREGRINA, Newberry.

(Plate XII. fig. 5 and 6.)

This is a much more interesting species than the last, as belonging to a generic or subgeneric form not hitherto recognized below the Carboniferous, and having its minute structure in part preserved.

The specimens are, like the last, on slabs of marine limestone of the Corniferous formation, and flattened. One represents an upper portion of the stem with leaf-scars and remains of petioles; another a lower portion, with aerial roots. The upper part is 3 inches in diameter, and about a foot in length, and shows thirty leaf-scars, which are about $\frac{3}{4}$ of an inch wide, and rather less in depth (fig. 5, *a*). The upper part presents a distinct rounded and sometimes double marginal line, sometimes with a slight depression in the middle. The lower part is irregular, and when most perfect shows seven slender vascular bundles, passing obliquely downward into the stem. The more perfect leaf-bases have the structure preserved, and show a delicate, thin-walled, oval parenchyma, while the vascular bundles show scalariform vessels with short bars in several rows, in the manner of many modern ferns. Some of the scars show traces of the hippocrepian mark characteristic of *Protopteris*; and the arrangement of the vascular bundles at the base of the scars is the same as in that genus, as are also the general form and arrangement of the scars. On careful examination, the species is indeed very near to the typical *P. Sternbergii*, as figured by Corda and Schimper*.

The genus *Protopteris* of Sternberg, though the original species (*P. punctata*) appears as a *Lepidodendron* in his earlier plate (pl. 4), and as a *Sigillaria* (*S. punctata*) in Brongniart's great work, is a true tree fern; and the structure of one species (*P. Cottai*) has been beautifully figured by Corda. The species hitherto described are from the Carboniferous and Permian.

The second specimen of this species represents a lower part of the stem (fig. 6). It is 13 inches long and about 4 inches in diameter, and is covered with a mass of flattened aerial roots lying parallel to each other. in the manner of the Psaronites of the Coal-formation and of *P. erianus* of the Upper Erian or Devonian.

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* Corda, Beiträge, pl. 48, copied by Schimper, pl. 52.

4. Rhachiopteris, n. sp.

(Plate XII. fig. 7.)

Along with the above, in Dr. Newberry's collection, is a singular fragment enclosed in a large nodule of chert from the Corniferous Limestone. It shows clearly about 8 inches of the base of an immense petiole, from 4 to 2 inches in breadth, and attached to shreds of tissue, which seem to represent a part of the stem torn away with it. Its structure is preserved, and consists of delicate large-celled parenchyma, with slender bundles of vessels, about eighteen of which are visible. In structure they are very similar to those of the last species; but the scalariform vessels are accompanied by more woody tissue. They are parallel in the distal end of the fragment, but near its base become tortuous and branching. In the part which represents the stem, or possibly part of its roots, they assume the form of cylindrical rods of parenchyma with a central bundle of vessels. In form and outward marking it resembles *R. gigantea* of my Royal-Society Memoir; but in the latter the structure is not preserved. The present specimen must have belonged to a tree fern of grander proportions than either of those previously noticed.

In the cellular tissue of some parts of this great petiole there are numerous round granules, resembling those figured by Corda in his description of *Protopteris Cottai* *, and supposed by that writer to be grains of fossilized starch. Mr. Carruthers has more recently described similar starch-granules in the tissues of an Eocene fern†. Whether the granules in the cells of the present specimen are really remains of starch, or merely rounded siliceous concretions, such as are often found in the cells of silicified plants, I am by no means certain. Perhaps the fact that similar round grains are seen in the interior of some of the woody fibres militates against their organic character. They are certainly not markings on the cell-walls, but spherical bodies contained within the cells; and if starch-grains, they may claim to be the oldest known, being of Middle Devonian age.

5. Nœggerathia gilboensis, n. sp.

(Plate XII. fig. 8.)

Leaf rhombic-obovate, with a broad base. Nerves or radiating plicæ nine in number, not forked, and with fine striæ between them. Length $3\frac{2}{10}$ inches. Breadth $2\frac{1}{2}$ inches.

This leaf occurs in the collections of Mr. Lockwood, from Gilboa. It belongs, without doubt, to the provisional genus *Nœggarathia*, and seems to have been bent in a conduplicate manner, and clasping or decurrent, on a stem or branch. It does not seem to have been a fern; but beyond this I am not inclined to hazard any opinion as to its affinities.

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* Beiträge, pl. 49.

† Quart. Journ. Geol. Soc. Aug. 1870.

In addition to this species and the *Caulopteris* above described, Mr. Lockwood's collection contains branchlets of a *Lepidodendron*, apparently *L. gaspianum*, which also occurs in Prof. Newberry's collections from the Corniferous Limestone.

6. Lycopodites, &c.

In his recently published 'Paléontologie,' Schimper (evidently from inattention to the descriptions and want of access to specimens) doubts the Lycopodiaceous character of the species of this genus described in my papers in the Journal of this Society from the Devonian of America. Of these *L. Richardsoni* and *L. Matthewi* are undoubtedly very near to the modern genus *Lycopodium*. *L. Vanuxemii* is, I admit, more problematical; but Schimper could scarcely have supposed it to be a fern or a fucoid allied to *Caulerpa* had he noticed that both in my species and the allied *L. pinnæformis* of Goeppert, which he does not appear to notice, the pinnules are articulated upon the stem, and leave scars where they have fallen off. When in Belfast last summer I was much interested at finding in Prof. Thomson's collection a specimen from Caithness, which shows a plant apparently of this kind, with the same long narrow pinnæ or leaflets, attached, however, to thicker stems, and rolled up in a circinate manner. It seems to be a plant in vernation, and the parts are too much crowded and pressed together to admit of being figured or accurately described; but I think I can scarcely be deceived as to its true nature. The circinate arrangement in this case would favour a relationship to ferns; but some Lycopodiaceous plants also roll themselves in this way, and so do the branches of the plants of the genus *Psilophyton*.

In conclusion, I may state that, when in Edinburgh last summer, Mr. Peach showed me fine and characteristic specimens of rhizomata of *Psilophyton* from the Caithness beds, and also specimens which seem to show that some at least of the fragments from these beds, which have been referred to *Lepidodendron nothum*, belong to a different species, more nearly allied to the *Cyclostigma* of Killercan and Gaspé. Mr. Peach has also branches of a *Lepidodendron* like *L. gaspianum*, a *Cyclopteris* allied to *C. Brownii*, a plant of the nature of *Anarthrocamia* or *Calamites*, a *Stigmaria*, and fragments which may belong to *Sigillaria*, all from the Devonian beds of Caithness.

EXPLANATION OF PLATE XII.

Fig. 1. *Caulopteris Lockwoodi*, one-fourth natural size, portion of stem with petioles.

Fig. 2. Leaf-scar, natural size.

Fig. 3. Restoration in part of *Caulopteris Lockwoodi*, reduced: *a*, upper part, with petioles; *b*, remains of pinnæ; *c*, middle part, with diverging aerial roots; *d*, lower part, with aerial roots, perhaps the same with *Psaronius erianus*, Dawson, MS.

Fig. 4. *Caulopteris antiqua*, Newberry, one-fourth the natural size.

Fig. 5. *Protopteris peregrina*, Newberry, impression of stem, one-fourth the natural size: *xx*, remains of petioles. 5 *a*, scar, natural size, showing bundles of vessels at base; 5 *b*, portion of a vascular bundle, magnified, showing scalariform vessels and cellular tissue; 5 *c*, scalariform vessel, highly magnified.

Fig 6. Lower part of stem of the same, with aerial roots, one fourth the natural size. 6 *a*, one of the roots, natural size.

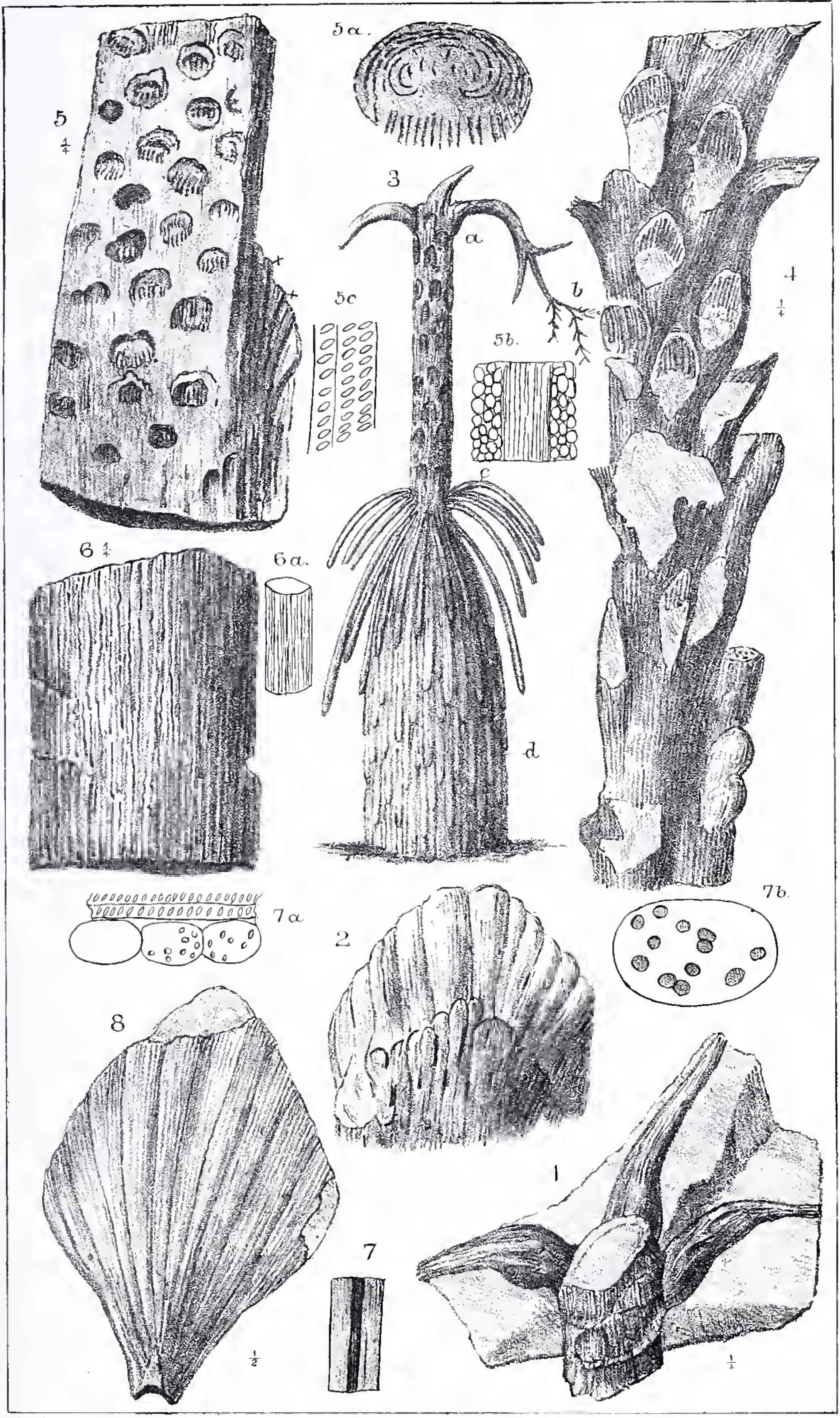
Fig. 7. Vascular bundle of *Rachiopteris*, natural size; 7 *a*, portion of the same, showing vascular and cellular tissue, with rounded granules in the cells; 7 *b*, one of the cells magnified, showing contained granules.

Fig. 8. *Næggerathia gilboensis*, one-half the natural size.

DISCUSSION.

Dr. DUNCAN doubted the desirability of basing generic and specific terms on imperfectly preserved and indistinct specimens, and pointed out the disagreements among botanists that had resulted from so doing. He would prefer calling fossils such as those described "cryptogamous forms from certain strata." He was doubtful also whether the supposed petrified starch was not merely orbicular silex.

The CHAIRMAN (Prof. Morris) remarked on the four different conditions exhibited by existing tree ferns:—first, with roots running down the stem; secondly, the lower portion with oval scars; these are, thirdly, further up the stem, rhomboidal vertically; and, fourthly, higher up still, rhomboidal horizontally; so that were the plant fossil, distinct genera and species might be founded upon the different parts.



R. Mintern lith.

Mintern Bros. imp.

DEVONIAN TREE FERNS & NŒGGERATHIA.

(*From the Monthly Microscopical Journal, August*, 1873.)

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

REMARKS ON MR. CARRUTHER'S VIEWS OF PROTOTAXITES.

By J. W. Dawson, LL D., F.R.S.

In the "Monthly Microscopical Journal" for October, 1872, Mr. Carruthers, of the British Museum, has published a paper in which he endeavours to show that my *Prototaxites Logani*, from the Devonian of Gaspé, is a gigantic seaweed, for which he proposes the generic name *Nematophycus*. Though I saw this article some time ago, other avocations have prevented me from attending to it until now.

The tone and manner of the article, I may say in passing, are unnecessarily offensive; and the author bolsters up his argument by unfair assumptions that I am ignorant of some of the most familiar facts of structural botany, facts which were well known to me while he was yet a school-boy, and which are stated or implied in many of my papers on fossil plants. Possibly, however, Mr. Carruthers is already aware of his bad taste in this matter, and it will be to me a sufficiently ungracious task to expose, as I must do in the interest of truth, the worthlessness of the explanation which he offers of the nature of Prototaxites. I shall reply to his objections under the following heads:—(1.) The mode of occurrence of Prototaxites. (2.) Its microscopic structure. (3.) Its probable affinities.

1. *Mode of Occurrence.*—This alone should suffice to convince any practical palæontologist that the plant cannot be a sea-weed. Its large dimensions, one specimen found at Gaspé Bay being three feet in diameter; its sending forth strong lateral branches, and gnarled roots; its occurence with land plants in beds where there are no marine organisms, and which must have been deposited in water too shallow to render possible the existence of the large oceanic Algæ to which Mr. Carruthers likens the plant. These are all conditions requiring us to suppose that the plant grew on the land. Further, the trunks are preserved in sand-

stone, retaining their rotundity of form even when prostrate; and are thoroughly penetrated with silica except the thin coaly bark. Not only are Algæ incapable of occurring in this way, but even the less dense and durable land plants, as Sigillariæ and Lepidodendra are never found thus preserved. Only the extremely durable trunks of coniferous trees are capable of preservation under such circumstances. In the very beds in which these occur, *Lepidodendra*, tree ferns and *Psilophyton*, are flattened into mere coaly films. This absolutely proves, to any one having experience in the mode of occurrence of fossil plants, that here we have to deal with a strong and durable woody plant.

These considerations were dwelt on in my published descriptions of Prototaxites, but they naturally have more weight in my judgment than in that of Mr. Carruthers. Geologists and palæontologists will appreciate them.

2. *Microscopic Structure.*—It would be tedious to go into the numerous scarcely relevant points which Mr. Carruthers raises on this subject. I may say in general that his errors arise from neglect to observe that he has to deal not with a recent but a fossil wood, that this wood belongs to a time when very generalized and humble types of gymnosperms existed, and that the affinities of the plant are to be sought with Taxineæ, and especially with fossil Taxineæ, rather than with ordinary pines.

Mr. C., after describing Prototaxites according to his own views of its structure, expresses the opinion that "the merest tyro in histological botany" may see that the plant could not be phænogamous. But if the said tyro will take the trouble to refer to the beautiful memoir on the Devonian of Thuringia, by Richter and Unger,[*] and to study the figures and descriptions of *Aporoxylon primigenium*,[†] *Stigmaria annularis*, *Calamopteris debilis*, and *Calamosyrinx Devonicus*, he will find that there are Devonian plants referred by those eminent palæontologists to Gymnosperms and higher Cryptogams, which fall as far short of Mr. Carruthers' standard as Prototaxites itself. Nothing can be more fallacious in fossil botany than comparisons which overlook the structures of those primitive palæozoic trees which in so many interesting ways connect our modern gymnosperms with the cryptogams.

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[*] Trans., Vienna Academy, 1856.

[†] I have elsewhere compared Aporoxylon with Prototaxites, 'Jour. Geol. Soc.' 1862, p. 306. Report on Devonian plants.

It is scarcely necessary to reply to such a statement as that the fibres of Prototaxites have no visible terminations. They are very long, no doubt, and both in this and their lax coherence they conform to the type of the yews. In Mesozoic specimens of *Taxoxylon* which I have now before me, the fibres are nearly as loosly attached and as round in cross section as in Prototaxites. In these, as in Prototaxites, water-soakage has contributed to make the naturally lax and tough yew-structure less compact, and to produce that appearance of thickness of the walls of the fibres which is so common in fossil woods.

Disks or bordered pores in Prototaxites I did not insist on, the appearance being somewhat obscure; but Mr. Carruthers need not taunt me with affirming the existence of such pores in the walls of cells not in contact. Pores, if not bordered pores, may exist on such cells, and the wood cells of Prototaxites are in contact in many places, as may easily be seen, and even where they appear separate, this separation may be an effect of partial decay of the tissues.

Mr. Carruthers converts the spiral fibres lining the cells of Prototaxites into tubes connecting the cells. This is a question of fact and vision, and I can only say that to me they appear to be solid, highly refracting fibres; and under high powers, precisely similar to those of fossil specimens of Taxoxylon from British Columbia, and to those seen in charred slices of modern yews. I may further say that Mr. Carruthers' figure (Plate XXXII.) is in my judgment to a great extent imaginary.

But what of the arrangement of these fibres. It is true that, as I have stated, they appear in some cases to pass from cell to cell, and I hesitated to account for this appearance. Mr. C. might, however, have spared himself the remark that "if Dr. Dawson knew anything whatever about a vegetable cell, and the formation of the spiral fibre in its interior, he would not have written such nonsense"—(a specimen, by the way, of the amenities of British Museum Science, as represented by Mr. C.) The possibilities of such an appearance, as yet, perhaps, unknown in the plant-rooms of the Museum, result from the following considerations: (1.) In more or less crushed fossil plants, it is not unusual to see what are really internal structures appearing to pass beyond the limits of the cell-wall, from the mere overlapping of cells. I have good examples in the Mesozoic Taxoxylon already mentioned. (2.) In fossil woods the original cell-wall is often entirely destroyed, and only the ligneous lining remains, perhaps thickened by incrustation of mineral matter within. In this case the original lining of the cell may seem to be an external structure. I have examples both in Mesozoic conifers and in carboniferous plants. Long soaking in water and decay have thus often made what may have been a lining of wood-cells appear as an intercellular matter, or an external thickening of the walls. (3.) In decayed woods the mycelium of fungi often wanders through the tissues in a manner very perplexing; and I suspect, though I cannot be certain of this, that some fossil woods have been disorganized in this way. At the time when my description was published, I felt uncertain to which of these causes to attribute the peculiar appearance of Prototaxites. I have now, from subsequent study of the cretaceous Taxineæ of British Columbia,* little hesitation in adopting the first and second explanations, or one of them, as probable.

Mr. Carruthers does not believe in the medullary rays of Prototaxites. The evidence of these is the occurrence of regular lenticular spaces in the tangential section, which appear as radiating lines in the transverse section. The tissues have perished; but some tissues must have occupied these spaces; and in fossil woods the medullary rays have often been removed by decay, as one sometimes sees to be the case with modern woods in a partially decayed state. Mr. Carruthers should have been more cautious in this matter, after his rash denial, on similar grounds, of medullary rays in Sigillaria and Stigmaria, contrary to the testimony of Brongniart, Goeppert, and the writer, and the recent exposure of his error by Professor Williamson. That the wood-cells have been in part crushed into the spaces left by the medullary rays is only a natural consequence of decay. The fact that the medullary rays have decayed, leaving the wood so well preserved, is a strong evidence for the durability of the latter. The approval with which Mr. C. quotes from Mr. Archer, of Dublin, the naïve statement that "the appearance of medullary rays was probably produced by accidental cracks or fissures," would almost seem to imply that neither gentlemen is aware that radiating fissures in decaying exogenous woods are a consequence of the existence of medullary rays, [or that water-soaked wood cannot be cracked in this way.]

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* Report of Geol. Survey of Canada, now in course of publication. The collections contain wood showing the structure of yew, cypress, oak, birch, and poplar, all from rocks of cretaceous age.

Perhaps the grossest of all Mr. Carruthers' histological errors is his affirming that some of my specimens of Prototaxites show merely cellular structures, or are, as he says, "made up of spherical cells." Now, I affirm that in all my specimens the distinct fibrous structure of Prototaxites occurs, but that in parts of the larger trunks, as is usual with fossil woods, it has been replaced by concretionary structure, or by that pseudo cellular structure which proceeds from the formation of granular crystals of silica in the midst of the tissues. Incredible though it may appear, I know it to be a fact, as all the specimens I gave to Mr. Carruthers had been sliced and studied by myself, that it is this crystalline structure which the botanist of the British Museum mistakes for vegetable cells.* I think it right to state here that I not only gave Mr. C. specimens in these different states of preservation, but that I explained to him their nature and origin.

It is unnecessary to follow further the histological part of the question, as my object is not so much to expose the errors of Mr. Carruthers as to illustrate the true structure of Prototaxites.

3. *Affinities.*—In discussing these I must repeat that we must bear in mind with what we have to deal. It is not a modern plant, but a contemporary of that "prototype of gymnosperms" *Aporoxylon*, and similar plants of the Devonian. Further, the comparison should be not with exogens in general, or conifers in general, but with Taxineæ, and especially with the more ancient types of these. Still further, it must be made with such wood partly altered by water-soakage and decay and fossilized. These necessary preliminaries to the question appear to have been altogether overlooked by Mr. Carruthers.

My original determination of the probable affinities of Prototaxites, as a very elementary type of taxine tree, was based on the habit of growth of the plant—its fibrous structure, its spirally-lined fibres, its medullary rays, its rings of growth, and its coaly bark, along with the durable character of its wood, and its mode of occurrence; and I made reference for comparison to other Devonian woods and to fossil taxine-trees.

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* In fossil-woods, the carbonaceous matter, being reduced to a pulpy mass, sometimes partly becomes moulded on the surfaces of hexagonal or granular crystals, in such a manner as to deceive very readily an observer not aware of this circumstance.

Mr. Carruthers prefers to compare the plant as to *structure* with certain chlorospermous Algæ, and as to *size* with certain gigantic Melanosperms, not pretended to show similar structure. This is obviously a not very scientific way of establishing affinities. But let us take his grounds separately. He selects the little jointed calcareous sea-weed *Halimeda opuntia*, as an allied structure, and copies from Kutzing a scarcely accurate figure of the tissue of the plant as seen after the removal of its calcareous matter.* He further gives a defective description of this structure; whether taken from his own observation or from Kutzing, he does not say. Harvey's description, which I verified several years ago, in an extensive series of examinations of these calcareous Algæ, undertaken in consequenceof a suggestion that Eozoön might have been an organism of this nature, is as follows:—"After the calcareous matter of the frond has been removed by acid a spongy vegetable structure remains made up of a plexus of slender longitudinal unicellular filaments constricted at intervals, and at the constrictions emitting a pair of opposite decompound, dichotomous, corymboso-fastigiate horizontal ramelli, whose apices cohere and form a thin epidermal or peripheric stratum of cells." It will be seen at once that this structure has no resemblance whatever to anything existing in Prototaxites, even as interpreted by Mr. C., and without taking into account the fact that *Halimeda opuntia* is a small calcareous sea-weed, divided into flat reniform articulations, to which this structure is obviously suited, as it would be equally obviously unsuited to the requirements of a thick cylindrical trunk, not coated with calcareous matter.

In point of size, on the other hand, Mr. Carruthers adduces the great *Lessonia* of the Antarctic seas, whose structure, however, is not pretended to resemble that of Prototaxites except in the vague statement of a pseudo-exogenous growth. Lessonia I have not examined, but the horny *Laminariæ* of our North American seas have no resemblance in structure to Prototaxites.

Nothing further, I think, need be said in reply to Mr. Carruthers' objections; and *Nematophycus* may be allowed to take its place along with a multitude of obsolete fucoids which strew the path of palæontology. As to Prototaxites, it is confessedly an obscure and mysterious form, whose affinities are to be discussed with caution, and with a due consideration of its venerable age and state of preservation, and probably great divergence from any of our modern plants; and it is to be hoped that ere long other parts than its trunk may be discovered to throw light on its nature. Until that takes place, the above remarks will be sufficient to define my position in regard to it; and I shall decline any further controversy on the subject until the progress of discovery reveals the foliage or the fruit of this ancient tree, belonging to a type which I believe passed away before even the Carboniferous flora came into existence.

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* A more characteristic figure is given in Harvey's "North American Algæ."

[*From the* Quarterly Journal *of the* Geological Society *for*
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ON THE MICROSCOPIC STRUCTURE OF STROMATOPORIDÆ, etc.

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OF
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On the MICROSCOPIC STRUCTURE *of* STROMATOPORIDÆ, *and on* PALÆOZOIC FOSSILS *mineralized with* SILICATES, *in illustration of* EOZOON.

By J. W. DAWSON, LL.D., F.R.S., F.G.S., &c.

[PLATES III.–V.]

AMONG the collateral subjects which have arisen in the discussions with respect to *Eozoon canadense*, two of the most important are:—1st, the question of its structural relations with the Palæozoic fossils of the genus *Stromatopora* and allied genera: 2nd, the occurrence in Palæozoic rocks of fossils mineralized with hydrous silicates akin to the serpentine and loganite found in some of the best-preserved specimens of the Laurentian fossil. For several years I have taken advantage of every opportunity to make collections illustrative of these questions, and to subject the specimens obtained to microscopic examination. In this I have been greatly aided by friends who will be mentioned in the sequel, and by the large number of excellent sections prepared by Mr. Weston, of the Geological Survey of Canada, for the late Sir W. E. Logan and for myself. In the following paper I purpose to state the conclusions arrived at as the result of these observations, with such portions as may be necessary of the large accumulations of facts on which they are based.

I. STROMATOPORIDÆ.

1st. *Microscopic Structure.*—The Stromatoporidæ have long been a zoological stumbling-block, and have been referred to Corals, Sponges, Foraminifera, and even to Hydractiniæ. I do not purpose to review these diverse opinions, most of which are undoubtedly based on imperfect acquaintance with the microscopic structure of these curious fossils, but to give an intelligible account of the structure of some typical species, preparatory to the consideration of their relation with *Eozoon*.

The genus *Stromatopora*, properly so called, is founded on the species *Stromatopora concentrica*, Goldfuss, and its allies, which range from the Upper Cambrian to the Devonian inclusive. Avoiding, for the present, complexities arising from the various states of preservation and of weathering, I may refer in the first instance to remarkably well-preserved specimens from the Corniferous Limestone of Ohio, and from the island of Marblehead in its vicinity, which have been placed in my hands by Mr. A. E. Walker of Hamilton, and Dr. Newberry of New York. In these the concentric laminæ and pillars of the fossil are in the condition of opaque calcite, apparently retaining its minute structure and not affected by crystallization; and the interspaces or chambers are occupied by transparent calcite, permitting all the structures to be very well seen, either on polished surfaces or in transparent slices*.

In these specimens about three interspaces and two laminæ occur in the space of a millimetre; and though neither the laminæ nor the interspaces are uniform in thickness, the latter are about twice the width of the former. In some places the laminæ rise into conical or rounded eminences with corresponding depressions; in others they are nearly flat and concentric, this difference being apparently accidental. The laminæ are connected with each other by pillars, which are either round or somewhat flattened (Pl. III. fig. 1). The texture of the laminæ is not spicular, but perfectly continuous and finely granular, as if made up of minute fragments of calcite. When the mass is broken parallel to the laminæ, the pillars appear as minute tubercles (Pl. IV. fig. 5), *but a true exterior surface is smooth.* The laminæ are pierced with numerous round pores about one tenth of a millimetre in diameter. Some of these pass through hollow pillars across one interspace into another; but the greater part pass through the laminæ from one interspace into the next. The laminæ themselves are here and there pierced with horizontal tubes which thicken the laminæ where they pass (Pl. III. fig. 3, *b*); they appear to traverse the laminæ obliquely from one space into another, or from the hollow pillars laterally. They may be called canals. In addition to the ordinary laminæ, some of the chambers or interspaces are subdivided by very thin secondary laminæ. In a few cases these are attached to ordinary laminæ as a sort of inner wall. The ordinary laminæ in the more regular specimens are often of great continuity, extending without interruptions for several square inches.

In some specimens there are a few rounded perforations, less than a millimetre in diameter, which extend vertically through several interspaces. Their walls are densely calcareous. They are often covered up with the growth of the laminæ, and seem to have no connexion with the other parts of the structure. I do not regard them as oscula, but as perforations of some parasitic animal; and I attribute to the same origin certain rounded cavities, similarly walled, in other parts of the mass.

The above is an accurate description of the most common type of *Stromatopora* when, as nearly as possible, in its natural condition. Other species of the genus, as now usually limited, differ principally in the thicknesses and distances of the laminæ, in the number and size of their perforations, and in their more or less tuberculated surfaces. In some species the pores are so numerous that the laminæ appear reticulated; in others the laminæ are so much thickened that the pores appear as tubuli. The pillars also differ somewhat in size and form. In the very numerous specimens which I have examined, I have convinced myself that while the laminæ are always porous they are never spicular, and that the so-called oscula are accidental. They are due either to the causes above referred to or to branches of *Syringopora* and similar corals included in the mass of *Stromatopora*.

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* These specimens are associated with a beautiful *Saccammina*, having a calcareous test, which I have described as *Saccammina eriana*.

It is evident from the above description that the animal matter of *Stromatopora* must have occupied the chambers or interspaces, and must have extended from chamber to chamber through the pores and hollow pillars. Such a structure is obviously that of a rhizopod rather than of a sponge. Further, the arrangement of the laminæ and pillars is very nearly allied to that of *Parkeria* and *Loftusia* as described by Carpenter and Brady, which I have myself studied in specimens kindly given to me by Professor T. R. Jones *. In so far as the hollow pillars and perforated plates are concerned, it has some points of correspondence, though more remote, with *Receptaculites*. The supposed oscula on which has been based a reference of these forms to sponges are certainly not constant. I have seen large masses of the form above described, presenting more than 30 square inches of surface, without a trace of an osculum; and in those specimens where tubular orifices appeared, I have found that they cut like perforations made by a boring instrument through the mass, irrespective of its structure, and that they were lined with continuous calcareous walls different from the laminæ of the fossil. It is scarcely necessary to say, after the above descriptions, that I attach no scientific value to the ingenious and elaborate attempt of Mr. H. J. Carter ('Annals and Magazine of Natural History,' ser. 4, vol. xix. p. 44) to prove that *Stromatoporæ* are skeletons of hydroids allied to *Hydractinia*. The resemblances of *Stromatoporæ* to these hydroids are altogether superficial, and depend on both having a parasitic and concentric habit of growth. In every essential character they differ entirely, and can have no close zoological affinity. In comparison with *Eozoon*, the general appearance and habit of growth are so similar that specimens cannot easily be distinguished by the naked eye, or where the minute structures are not preserved. In microscopic structure the thin laminæ of *Stromatoporæ* correspond to the proper wall of *Eozoon*. The thickening of the walls corresponds to the supplemental skeleton, and the horizontal tubes to the canals, while the interspaces and the pillars correspond to the chambers and connecting walls of the older fossil. The main structural difference is, that while *Eozoon* has a delicately tubulated proper wall of Nummuline type, that of *Stromatopora* has coarser perforations and pores. *Stromatopora* and *Eozoon* may both be regarded as large sessile laminated calcareous Rhizopods; but the former presents a less generalized type than the latter, which combines structures that were usually separated even in the Palæozoic period.

Stromatoporæ of the type above described are abundant in the Corniferous Limestone. They occur throughout the Upper Silurian and are especially abundant and of large size in the Niagara Limestone, where they abound even in those Dolomitic beds that contain few other fossils. They are also abundant in the Dolomite of the Guelph Limestone; and it is perhaps not accidental that both here and in the Laurentian, fossils of this structure are associated with magnesian rocks. They occur also in the Lower Silurian, though less abundantly; and the oldest specimen I have seen is in the Potsdam Sandstone; and this, its structure not being preserved, may have belonged to *Eozoon* rather than to *Stromatopora*. The Lower Silurian species have usually very thin and continuous walls. In the great Niagara Limestone, as seen at Niagara Falls, the masses of *Stromatopora* occur precisely as *Eozoon* occurs in the Laurentian limestones, and are mineralized with quartz and dolomite, and often almost entirely converted into crystalline masses, though occasionally showing their structure in great perfection.

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* More recently I have also studied the remarkably beautiful species of *Loftusia* from British Columbia described by Mr. G. M. Dawson, which confirm the resemblance of these specimens to *Stromatoporæ* (see his paper read before this Society, *infrà*, p. 69).

Certain beds of the Niagara formation, near Hamilton, contain not only *Stromatoporæ*, but multitudes of sponges; and through the kindness of Lieutenant-Colonel Grant, of that place, I have been enabled to examine a number of specimens of these, and to compare them with *Stromatoporæ*. These sponges are all siliceous and spiculate, and belong chiefly to two or three species of *Astylospongia* of Römer, and to *Aulocopina* of Billings, of which his *A. Grantii* is the type. The species of *Astylospongia* present a most regular and beautiful hexactinellid structure, as perfect as that in the sponges of the Cretaceous, showing even the hollow nodes, which have been supposed to be absent in the Palæozoic Hexactinellidæ. *Aulocopina* has a different structure, presenting series of hexagonal tubes built up with interlaced spicules, and giving off bundles of spicules in a radiating manner. These sponges are thus entirely distinct, both in material and structure, from the contemporary *Stromatoporæ*, and there is no link of connexion whatever.

The species included in the genera *Caunopora* of Phillips and *Cœnostroma* of Winchell, and in part in *Syringostroma* of Nicholson, and which may be represented by the *Stromatopora polymorpha* of Goldfuss, have the horizontal canals largely developed in laminæ thickened by supplemental deposit, and traversed by an infinity of minute canaliculi or ramifications of the canals opening at their surfaces. The horizontal canals radiate from central points where they are connected with vertical tubes or groups of tubes penetrating the whole thickness of the mass (Pl. IV. fig. 9, and Pl. V. fig. 10). The whole organism thus becomes divided into a series of vertical systems, which often very much obscure the concentric lamination, and in different states of preservation give very perplexing appearances. They may all be explained by bearing in mind that the horizontal canals, like those of *Stromatopora* proper, pass in the substance of the laminæ, now much thickened, and that at the centres of the systems they descend through the chambers by vertical tubes or groups of tubes which correspond to the hollow pillars of *Stromatopora*.

A great number of specimens of *Caunopora*, *Cœnostroma*, and allied forms, both European and American, have passed through my hands; but I was unable to decide, except inferentially, as to their minute structure, till I was so fortunate as to obtain, through the kindness of Mr. Selwyn, Director of the Geological Survey of Canada, a specimen collected by Professor R. Bell on the Albany River, Hudson's Bay, in rocks of Upper Silurian age. In this specimen the skeleton remains as carbonate of lime, while the canals and tubes are in great part empty, so that their minute ramifications are in the condition of a recent specimen, and can be injected with colouring-matter. The actual structures thus presented are as follows:—

Laminæ thin and obscure. Chambers almost entirely filled with supplemental deposit, traversed by innumerable microscopic horizontal canaliculi, which are tortuous and anastomose frequently. They are connected with systems of radiating canals which terminate centrally in vertical tubes traversing the whole thickness of the specimen, and opening at the surface in round pores visible to the naked eye and placed on the summits of slight eminences. The pores are about 4 millimetres apart horizontally. The upper surface is smooth and does not show the radiating canals, but these are disclosed by erosion or by horizontal fracture. This species closely resembles Hall's *Caunopora incrustans*, from the Devonian of New York; but the pores are more regular and less than half as far apart, and the radiating tubes are more numerous. For the above species I have proposed the name *Caunopora hudsonica* (Pl. IV. fig. 9 and Pl. V. fig. 10).

I have described in a former publication* a fossil preserved in a similar way, but less perfectly, and which has vertical tubes in groups instead of singly; it is from the Galt Limestone of Ontario, and belongs to the genus *Cœnostroma*, as limited in the sequel. I would propose for it the name *C. galtense*.

The structures in *Caunopora* and *Cœnostroma* are unquestionably, at first view, more akin to those of sponges than are those of the typical *Stromatopora*, as the vertical tubes may be taken for oscula, and the extremities of the fine tubes for the incurrent pores. On the other hand, the solidity of the calcareous walls and supplemental thickenings is at variance with such a view; and in many respects they more nearly resemble *Eozoon* than any of the Palæozoic fossils with which I am acquainted. The canal-system in both is, indeed, so much alike that it would not be easy to distinguish it, except that *Eozoon* wants the continuous vertical tubes and possesses a true nummuline wall.

The minute structures of such species as the *Stromatopora nodulata* of Nicholson (*S. sanduskyana* of Röminger, Pl. V. fig. 11), connect the true *Stromatoporæ* with the species of the genus *Cœnostroma*; and these, by confluence of the separate tubes, pass into those of the genus *Caunopora*.

Of the species separated by Nicholson in the genus *Syringostroma*, that which he has named *S. columnaris* is a very peculiar type. It is penetrated vertically by what seem to be solid columns, and which, on microscopical examination, prove to result from upward bending and fusion of the laminæ along certain vertical lines. The effect is obviously to give much additional strength to the skeleton. Between

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[*] 'Life's Dawn on the Earth,' p. 160.

the columns the laminæ are supported by pillars as in *Stromatopora.* They are also penetrated by horizontal canals which ramify radially, and are connected with vertical tubes as in *Cœnostroma*, to which this form is very closely allied; I have seen only one species from the Corniferous Limestone, specimens of which have been kindly given to me by Dr. Newberry and Mr. Hinde of Toronto.

Dictyostroma of Nicholson includes species in which the connecting pillars are formed by upward bending of the laminæ themselves in conical points. The only species described by Nicholson (*D. undulatum*) is from the Niagara formation of Louisville, Kentucky. I have, however, seen an imperfectly preserved specimen with this structure from the Black-River Limestone of Port Claire. Mr. Hinde has sent me another from the Corniferous of Port Colborne. These seem to be different from Professor Nicholson's species in the distance between the laminæ, which is much less than in the coarsely constructed species which he has described. The laminæ are porous in these specimens; but I have seen no vertical tubes or oscula.

The species *Stromatopora compacta*, from the Trenton Limestone, described by Billings, and which is not uncommon, does not appear to belong to this group of organisms. It consists of very minute hexagonal tubes with extremely thin walls and well-developed tabulæ, which, from their strong development and continuity, give in some specimens an appearance of concentric lamination. The species seems to belong to the genus *Stenopora*, but its cells are excessively minute. Corals of the genus *Fistulipora*, with small tubes imbedded in a cellular cœnenchyma, may readily, in certain states of preservation, be mistaken for *Stromatopora.*

Stromatoporæ seem not unfrequently to have overgrown corals of different species; and, in the case of *Syringopora*, the tubes of these projecting through the mass often simulate oscula. Mr. Hinde informs me that, in the case of one species, this association is so common that it suggests the idea of a case of "commensalism."

As connected with *Stromatopora*, it may be well to remark that some misapprehension still appears to exist respecting *Archæocyathus*, a fossil of the Cambrian rocks of Mingan, Labrador, and of which several species have been described by Billings. Of these the only one I have studied is *A. profundus.* This is certainly a calcareous, chambered organism, with pores connecting the chambers, and must have been the skeleton of a Rhizopod. The other species have similar structures. It is true, however, that on treating them with acids, Billings obtained siliceous spicules in the matrix, which I have myself examined. I regard them as having belonged to lithistid sponges of the genus *Trichospongia* of Billings, accidentally associated with the *Archæocyathus.*

Some specimens of *Stromatopora* present remarkable lines of growth, caused by the appearance of two or three layers of smaller cells at intervals of seven or eight interspaces (Pl. IV. fig. 4). The preservation of these without the intervening portions may, in some cases, account for the abnormally wide interspaces sometimes seen in imperfectly preserved specimens. I have not been able to satisfy myself whether these lines of growth are of specific value. In one specimen from the Devonian of Iowa, a *Stromatopora* of this type presents large vertical tubes which extend from one growth-line to the next, but are sparsely distributed through the mass, and not connected with radiating tubes as in *Caunopora*.

Another interesting structure, seen in a species from the Corniferous Limestone, usually, though perhaps incorrectly, identified with *S. concentrica*, is the division of the pillars at their summits into branches (Pl. III. fig. 2), so as to support at many points the layer above, which in this case is thin and not much strengthened with supplemental deposit.

2nd. *State of Preservation.*—*Stromatoporæ* have apparently always been calcareous when recent. They are sometimes preserved in the state of calcite with the chambers either filled with the same material or with silica. Sometimes they are entirely silicified, or the laminæ and pillars are silicified and the chambers filled with calcite. Occasionally the chambers are filled with dolomite or the whole structure is dolomitized.

A specimen of the type of *S. concentrica* from the Devonian or Upper Silurian of James's Bay is now before me, and affords a good illustration of modes of preservation in silica. In some places the laminæ and pillars have been silicified, while the chambers are filled with limestone. When weathered or treated with acid, these portions show the whole structure very clearly, including the perforations of the laminæ and the hollow pillars (Pl. IV. fig. 7). Other portions have the chambers also filled with silica, the laminæ being distinguishable by their less transparent and porous character. In these portions the laminæ and pillars have usually been first coated over with minute crystals of quartz. A layer has then been deposited of chalcedony with botryoidal surfaces, and finally the remaining cavities have been filled with crystalline vitreous quartz. In the greater part of the specimen, however, the chambers have been filled with silica, while the laminæ have remained as calcite, and these portions, when weathered, present the appearance of thick structureless laminæ separated by thin spaces and penetrated by numerous round holes representing the pillars. Portions in this state might be mistaken for a coral of the type of *Fistulipora*, but in certain aspects they present that lobated amœboid form which is so characteristic of similarly preserved specimens of *Eozoon*.

In specimens of *Stromatopora* from the Niagara Limestone, it not unfrequently happens that certain layers or groups of layers are silicified, while others alternating with them remain as calcite. In this case, when the specimens are weathered, they present distant concentric layers very different in appearance from the actual structure.

As with other fossils, crystallization plays strange freaks with *Stromatoporæ*, reducing them to such a condition that, but for the partial preservation of portions here and there, they might be mistaken for inorganic bodies. This is well seen in the abundant *Stro-*

matoporæ of the great dolomite-beds of the Niagara Limestone. Of these many are entirely reduced to crystalline masses of quartz or dolomite, except small portions at the surface, while others have become hollow and resemble cavities lined or filled with crystals. In the Upper Silurian dolomite of Guelph, in like manner, there are specimens which have been converted into a granular dolomite, in which, however, the laminæ and, in some cases, the canals are more or less apparent.

The study of *Stomatoporæ* in these different conditions throws great light on the appearances presented by *Eozoon* in various states of preservation, and forms a guide to the interpretation of these, which should be before the mind of every one who desires to form correct opinions on the subject.

Since writing the above, I have seen the remarks of Dr. Nicholson on the calcareous nature of *Stromatopora*, and Zittel's observation of the occasional calcification of the spicules of siliceous sponges, as reported in the 'Geological Magazine' for January 1878. It had not occurred to me that any one acquainted with *Stromatoporæ* would doubt their calcareous nature; but Nicholson has sufficiently disposed of such doubts by the consideration that the *Stromatoporæ* are found silicified only in beds in which corals and shells have suffered the same change. Nor had it seemed necessary to refer in this connexion to the replacement of siliceous spicules with calcite. It is, or should be, well known from the behaviour of siliceous spicules with alkalies, and when heated, that many of them are not purely siliceous, but contain animal matter. This, with the more soluble character of their silica, enables them to be changed or removed without affecting the siliceous matrix. Hence in the siliceous sponges from the Niagara Limestone the spicules are sometimes opaque and granular in appearance, or have disappeared altogether, or have been replaced with calcite or with iron pyrite. These changes are, however, rare, and have no bearing on the calcareous nature of *Stromatopora*.

3rd. *Classification of Stromatoporidæ.*—It is not my purpose to enter into any revision of the numerous species of this family, or to attempt to summarize the work which has been done with reference to the American species by Hall, Winchell, Nicholson, Billings, Röminger, and others. It may, however, be useful to state the results at which I have arrived with reference to the leading generic forms.

1. *Stromatopora* (Goldfuss, 1827).—In the original definition by Goldfuss the genus is characterized as exhibiting "alternating strata of a solid and porous character." The porous strata in this definition are the real laminæ, the solid strata are the filled-up chambers; and according as one or the other is preserved, we have in this type thin laminæ connected by pillars, or thick laminæ perforated with round holes and separated by vacant spaces. The typical species is *S. concentrica* of Goldfuss, and the genus may be held to include all the species with thin or moderately thick laminæ connected with solid and hollow pillars and perforated with minute pores, or having

a reticulated texture. *Stromatocerium* of Hall is a synonym. The genus ranges from the Upper Cambrian to the Devonian inclusive, and it is not easy to separate the species which have been described.

2. *Caunopora* (Phillips, 1841).—The typical species, *C. placenta*, is defined by Phillips as "amorphous," composed of concentric or nearly plane masses perforated by flexuous or vermiform small tubuli and by larger straight subparallel or radiating open tubes, persistent through the mass. This definition includes those species with simple tubes giving origin to radiating tubuli passing through the thickened laminæ. *Cœnostroma* (*Caunopora*) *incrustans* of Hall is a typical American species, as is also *Caunopora hudsonica* above referred to.

3. *Cœnostroma* (Winchell, 1867).—This genus, as defined by its author, includes those species in which the radiating tubes diverge from the surfaces of little eminences raised in the concentric lamellæ; but, as Hall has well remarked, the presence or absence of eminences is a trivial character. The real distinction should be based upon the absence of the central simple radiating tubes, which in these species are represented by a group of more or less divergent ascending tubuli, so that the surface of the last layer presents eminences not with a single large pore at the summit, but with several small pores diverging from their sides. My *Cœnostroma galtense* above referred to and Hall's *Caunopora* (*Cœnostroma*) *planulata* are typical forms. I have been obliged to reverse the generic names as used by Hall, in the twenty-third Report of the Regents of New York, in the manner above stated, as Phillips's name certainly applies to the species with *single* vertical tubes.

Stromatopora nodulata of Nicholson (Ohio Report, vol. ii.) probably belongs to this genus.

4. *Syringostroma* (Nicholson, 1875).—This genus is defined by the author as composed of concentric laminæ and vertical pillars which are so thickened and so amalgamated with one another as to leave nothing but the most minute rounded cells. Laminated tissue traversed by numerous large irregularly disposed horizontal canals. The species *S. densa* included under this genus in the Ohio Report is undoubtedly to be referred to *Cœnostroma* as above defined, being a species with the vertical tubes small and the radiating tubes very large. The species *S. columnaris* has, however, a very special character in the apparent want of vertical tubes, and in the coalescence of the laminæ along certain vertical lines, giving solid columns terminating in imperforate or microscopically perforate tubercles at the surfaces.

5. *Dictyostroma* (Nicholson, 1875).—In this genus the upper surface of each lamina is developed into conical points which support the lamina above instead of pillars. The laminæ have horizontal canals, and the upper surface is apparently solid, though, no doubt, minutely perforate; the irregular oscula referred to by Nicholson are probably accidental. *D. undulata*, Nicholson, is the typical species; but I think we may add to these several others in which

the thin laminæ extend upwards in conical forms instead of pillars, and in some of which the laminæ are thin and apparently destitute of the horizontal tubes.

It is not impossible, though the specimens in my possession are not sufficiently perfect to render this certain, that *Labechia conferta* of Edwards and Haime, from the English Wenlock, may be allied to this or the last genus.

[The above descriptions of Stromatoporidæ were written before the publication of Nicholson and Murie's excellent memoir in the Journal of the Linnean Society, which reached me only a few days before the proof of the above pages. Their descriptions of the structures, and views as to the classification and affinities, agree in the main with those above given, and where they differ deserve careful consideration. They do not seem to have met with so good examples of the hollow pillars and perforated laminæ as those I have described, nor to have so distinctly observed the relation of the horizontal canals to a supplemental deposit of calcareous matter. In their comparison with *Parkeria* too much importance is, I think, attached to the arenaceous character of that fossil—a character which we find in living Rhizopods associated with forms not dissimilar to those which are calcareous. It is also not improbable that some Stromatoporidæ are built up of microscopic calcareous grains. *Loftusia* likewise presents points of comparison of some importance; and the Carboniferous species of that genus described and figured by Dr. G. M. Dawson (see p. 69) is especially instructive. In the memoir in question the genus *Syringostroma* of Nicholson is divided into *Stylodictyon* and *Pachystroma*, *Stromatocerium* of Hall is retained as a separate genus for some peculiar Stromatoporidæ of the Lower Silurian, and a new genus (*Clathrodictyon*) is formed for vesicular species without pillars. The separation of forms contained in *Syringostroma* I have myself suggested above; and I think the grounds for retaining *Stromatocerium* and adding *Clathrodictyon* may be sustained. The authors should, however, I think, have retained *Cœnostroma* of Winchell, and placed in it some forms which they have distributed in other genera. The new facts stated respecting *Labechia* are important with reference to that somewhat problematical fossil.]

The geological distribution of the American Stromatoporidæ known to me may be stated as follows, though the species, no doubt, require some revision :—

Potsdam formation	Stromatopora, sp.
Trenton formation	Stromatopora rugosa, *Hall.* Dictyostroma ? sp.
Niagara formation	Stromatopora concentrica, *Goldfuss.* Cœnostroma constellatum, *Hall.* Caunopora hudsonica, n. sp. Dictyostroma undulatum, *Nicholson.*
Guelph formation	Stromatopora ostiolata, *N.* Cœnostroma galtense, n. sp.

Corniferous formation	Stromatopora granulata, *Nicholson.*
	S. mammillata, *N.*
	S. Hindei, *N.*
	S. perforata, *N.*
	S. ponderosa, *N.*
	S. substriatella, *N.*
	S. tuberculata, *N.*
	Syringostroma columnare, *N.*
	Cœnostroma densum, *N.*
Hamilton formation	Stromatopora nux, *Winchell.*
	S. cæspitosa, *W.*
	Cœnostroma monticulifera, *W.*
	C. pustulifera, *W.*
Chemung formation	Stromatopora expansa, *Hall.*
	S. erratica, *H.*
	S. alternata, *H.*
	Caunopora incrustans, *H.*
	Cœnostroma solidulum, *H.*
	C. planulatum, *H.*

II. Palæozoic Fossils associated with Serpentine and other Hydrous Silicates.

Fossils having their cavities and pores infiltrated with hydrous silicates are much more abundant in Palæozoic limestones than is usually imagined. In some instances serpentine itself is found to have been concerned in such infiltration: while in other cases the infiltrating hydrous silicates are found to approach to pollyte, fahlunite, and other minerals which have usually been regarded as products of decomposition or metamorphism, but which, as Dr. Sterry Hunt has justly remarked, cannot reasonably be referred to such an origin when they are found filling the pores of Crinoids and other fossils in strictly aqueous deposits. In this case they must surely be the results of original deposition in the manner of glauconite; and, as we shall find, they sometimes appear to be strictly the representatives of that mineral, which occurs under similar conditions in other parts of the same formations.

1. *Serpentine of Lake Chebogamong.*—Mr. Richardson, of the Geological Survey, has observed, north of the Laurentian axis, on the Saguenay River, certain rocks which appear to be similar in mineral character to the Quebec group of Sir William Logan, and occupy a geological position intermediate between the Laurentian and the Trenton formation. Among these he describes a band of serpentine associated with limestone at Lake Chebogamong, which lies about 200 miles to the N.E. of Lake St. John, in a little-explored region. Among the few specimens which Mr. Richardson was able to bring back with him was one of extreme interest—a specimen apparently from the junction of the limestone and serpentine, and containing a portion of a tabulate coral, of which some of the cells are filled with a mixture of serpentine and calcite, and some with calcite. The serpentine seems to have been weathered; it has a granular, uneven appearance, and under the microscope shows patches with fibrous structure like chrysotile. There are also whitish serpentine veins, fringed with chrysotile or a mineral re-

sembling it under the microscope. The cell-walls of the coral are perfectly black and opaque, and probably carbonaceous. The coral found thus mineralized was examined by Mr. Billings, who had no doubt of its nature, though uncertain as to its generic affinities. After careful study of it, I am disposed to refer it to the genus *Astrocerium* of Hall, and it is not distinguishable in structure from *A. pyriforme* of that author, a species very common in the Upper Silurian limestones of the region in which the specimen occurs. The genus *Astrocerium* is specially characteristic of the Niagara formation; and though Edwards doubts its distinctness from *Favosites,* I think there are constant points of difference, especially in the microscopic characters of the cell-walls, which entitle it to be separated from that genus. In such specimens of *Astrocerium* as are well preserved, the walls of the hexagonal cells seem to have been of corneous texture, with minute corneous spicules instead of radiating septa. They have pores of communication, and there are also occasional larger pores or tubes in the angles of the cells. The tabulæ are very thin and apparently purely calcareous. This accounts for the singular fact, mentioned by Hall, that the cell-walls are sometimes entirely removed, leaving the tabulæ in concentric floors like those of *Stromatopora.* I think it likely that the typical species of *Astrocerium* may have been inhabited by Hydroids, and may have been quite remote from *Favosites* in their affinities.

The formation in which the serpentine and limestone of Lake Chebogamong occur is described as consisting of chloritic slates, in some places with hornblende crystals, dolomites, and hard jaspery argillaceous rocks. Upon these rest conglomerates and breccias with Laurentian fragments, and also fragments of the rocks before mentioned, and on these lie the limestone and serpentine. The serpentine has been analysed by Dr. Hunt, who finds it to contain chromium and nickel, and in this respect to be similar to that of the Quebec group, and not to that of the Laurentian*. The fossil would give evidence of a much later date than that usually attributed to rocks of the character above stated; but it is quite possible that there may be two series of different ages in the region, the lower being Lower Silurian or perhaps older, and the upper of Upper Silurian age. If the serpentine belongs to the newer formation, its association with a coral of the genus *Astrocerium* would of course be quite natural. If it belongs to the older formation, and the overlying limestone to the newer, the serpentine in the latter may be a *remanié* silicate derived from the older rocks and mixed with the limestone at their junction.

2. *Serpentine of Melbourne.*—The serpentines of this place belong to a great series of more or less altered rocks extending through the province of Quebec, and referred by Sir William Logan, on stratigraphical grounds, to his Quebec group, equivalent to the Arenig or Skiddaw series of England †. In ascending order these rocks at Melbourne present first a thick series of highly plumbaginous schists

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* Report of Geological Survey of Canada, 1870–71.

† Hunt, however, holds that these rocks are in part Huronian.

or shales, with thin bands of limestone holding fragments of Lower Silurian corals and crinoids. These pass upwards into a thick series of slaty rocks characterized by the prevalence of a shining crystalline hydro-mica, and known as nacreous or hydro-mica slates. They are associated with quartzose bands, and also with lenticular layers of crinoidal limestone. Parallel with these beds and, according to Logan's observations, overlying them, is the series containing the serpentine, which is associated with layers of limestone and nacreous slate, and also with brecciated and arenaceous beds, probably originally tufaceous, with beds of anorthite, steatite, and dolomite, and also with red slates. the whole forming a miscellaneous and irregular group, evidently resulting from the contemporaneous action of igneous and aqueous agencies, and affording few traces of fossils. The serpentines, which occur in thick and irregular beds, are different in colour and microscopic texture from those of the Laurentian system, and also present some chemical differences, more especially in the presence of oxides of nickel, chromium, and cobalt, and of a larger percentage of iron and a smaller proportion of water*.

These serpentines are undoubtedly bedded rocks and not eruptive; but they may have originated from the alteration of volcanic materials†. They appear, shortly after their original deposition, to have been broken up, so as in many places to present a brecciated appearance, the interstices of the fragments being filled with limestone and dolomite, which themselves are largely mixed with the flocculent serpentinous matter, and traversed by serpentinous veins sometimes compact and sometimes fibrous. Besides the very impure limestone thus occurring in the serpentinous breccia, there are also true layers or beds of limestone and dolomite included in or near to the great serpentine band. No well-preserved fossils have been found either in these beds or in the brecciated serpentine; but on treating the surfaces of slabs with an acid or making thin slices, fragments of organic bodies are developed which well illustrate the manner in which serpentine, whatever its origin, may be connected with the mineralization of such fragments.

It is to be observed here that the irregular bedding of the serpentine, and the apparent passage on the line of strike into dolomite and red slate, might accord either with a purely aqueous and oceanic mode of deposition like that of glauconite, or with deposition as beds of volcanic sediments, afterwards altered and partly redeposited by water. The association with ash rocks and agglomerates would, however, tend rather to the latter view, as would also the chemical characters of the serpentine already referred to; but the association with fossils mentioned below tends to show that at least a part of the mineral is an ordinary aqueous deposit. It is also to be observed, with reference to the superposition of serpentine on fossiliferous Lower Silurian rocks, that a similar relation is affirmed by Murray to occur in Newfoundland, where massive serpentines overlie unaltered fossiliferous rocks of the Quebec group*.

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* Under the microscope the Laurentian serpentines are usually homogeneous and uncrystalline, but with the structure of netting veinlets which I have elsewhere called septariform. The Melbourne serpentines usually present a confused mass of acicular crystals or a fibrous structure, and, where structureless, polarize more vividly than those of the Laurentian.

† Sandberger (Essay on Metallic Veins) quotes many German chemists to the effect that "olivine rock and the serpentine formed from it always contain copper, nickel, and cobalt." This origin might thus apply to the serpentines in the Quebec group in Canada, but not to those of the Laurentian, as I have already urged on other grounds in my reply to Hahn, in the 'Annals and Magazine of Natural History,' 1876, vol. xviii. pp. 32, 33.

No fossils have been found in the compact serpentine, but only in the limestone paste of the brecciated masses and in the limestone bands interstratified. The limestone of the breccia contains not only angular fragments of serpentine but disseminated serpentine and small veins of the same mineral. Its fossils are limited to small tubular bodies, crinoidal joints, and fragments, apparently of *Stenopora*, very imperfectly preserved. The tubular bodies may be portions of *Hyolithes* or *Theca*. Their interior is usually filled with dolomite; their walls are in the state of calcite; and they are incrusted with an outer ring of serpentine. In some instances the calcareous organic fragments are seen to be filled in the interior with serpentine. The crinoidal fragments are in a similar condition, the serpentine having apparently surrounded them in a concretionary manner after the cavities had been filled with dolomite. Fragments of calcite, dolomite, or older serpentine included in the limestone, and of no determinate form, are enclosed in the new or *remanié* serpentine in like manner, and in some cases this newer or coating serpentine was observed to have a fibrous structure. The serpentine thus coating and filling fossils and fragments is of a lighter colour than the serpentine of the fragments themselves, and in this respect resembles that of the small veins traversing the limestone. Such traces of fossils as exist in the layers of limestone are similar to those in the breccia, but not, so far as observed, coated with serpentine.

It would thus appear that, contemporaneously with the original deposition of the serpentine, thin bands of limestone were laid down, with a few fragments of crinoids, corals, and shells; that subsequently, but perhaps within the same geological period, and while the deposition of serpentine was still proceeding, portions of the surface of the serpentine were broken up and imbedded in limestone; that the fissures of this limestone were penetrated with serpentine veins, and its few fossils coated with that mineral, which also forms flocculent laminæ in the limestone.

The mode of deposition of this Palæozoic serpentine is thus considerably different from that of the Laurentian, which forms layers intimately interstratified with great limestones, and also nodules, concretionary grains, and fillings of fossils in these limestones. This difference in mode of occurrence is, no doubt, connected with the difference in composition of the two varieties of the mineral already noticed. In both cases, however, the serpentine has been so deposited that it could take part in the mineralization of marine organic remains.

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* Bedded serpentines also occur in unaltered Silurian dolomites at Syracuse in New York (Hunt, Chem. and Geol. Essays, p. 310).

The condition of the fragments of Silurian fossils in the limestones associated with the nacreous or hydro-mica slates is of interest in connexion with this subject. The shining laminated mineral associated with these fossils has been regarded from its chemical composition as a hydro-mica. Under the microscope, however, it shows a want of homogeneity which suggests the presence of two or more silicates, or the association of crystals of hydrous mica with minute grains of siliceous matter of some other kind. Though now highly crystalline, it must originally have been a fine sediment, since it fills the finest cells of *Stenopora* and *Ptilodictya*. Nor can its present state have been produced by any extreme metamorphism, as the undistorted state of these fossils amply testifies. Further it is interesting to observe that though the hydrous silicate is little magnesian, the fossils themselves are not infrequently converted into dolomite. In these fossiliferous beds there are also tabular crystals, apparently of anhydrous mica, little groups of crystals of tremolite, cavities filled with quartz, and crystalline grains of a mineral having the microscopical characters of olivine; and these have been developed or included in the mass without injury to the structures of the most delicate corals.

Similar appearances are presented by limestones from other parts of the Quebec group, of which a great series of slices has been prepared by Mr. Weston under the direction of the late Sir W. E. Logan, who, in his later researches in this group of rocks, gave much attention to the microscopic fossils in the more altered beds, as a means of determining their ages. Besides large series from Melbourne and its neighbourhood, I have examined slices from Stanford, Farnham, Cleveland, Bedford, Orford, Arthabaska, Point Levi, Rivière du Loup, and other places, in most of which Lower Silurian fossils occur associated with hydrous silicates.

The fossils above referred to occur in rocks undoubtedly of Lower Silurian age, and regarded as altered or metamorphosed members of the Quebec group. In the unaltered representatives of these rocks at Point Levi and the island of Orleans there occur considerable quantities of a true glauconite, which has been analyzed by Dr. Hunt, and which is without doubt an original deposit in the sandy and argillaceous beds in which it occurs, which in many cases are precisely similar to Cretaceous greensands. Dr. Hunt's analysis shows that this glauconite contains alumina, iron, potash, and magnesia, and thus approaches to the Laurentian loganite. In the forms of its little concretions it resembles the serpentine grains in the Laurentian limestones; and like modern glauconite it has moulded itself in organic forms. Some of these are spiral or multilobate, as if casts of minute univalve shells or of spiral and textularine Foraminifera*. Others are annular or are arcs of circles, and some present a delicate fibrous or tubulated appearance, as if they had moulded themselves on porous shells or very minutely-celled corals, spicules of sponges, &c. Shreds of corneous Polyparies, perhaps of Graptolites, abound in the matrix, but are not connected with the glauconite grains. Unfortunately there are no *Stromatoporæ* in these beds, otherwise we might have an almost precise recurrence of the relations of serpentine with *Eozoon* in the Laurentian*.

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* Ehrenberg has found casts of rotaline and textularine Foraminifera in Lower Silurian beds in Russia; and such forms occur in Upper Silurian limestones in Nova Scotia.

Another appearance which may be mentioned in this connexion occurs in certain beds of Utica Slate in the vicinity of the trappean mass of Montarville, and converted into a hard sonorous rock. In one of these are stems of crinoids which have retained their external form, while the calcareous material has been entirely removed and replaced by a soft green crystalline mineral whose physical and microscopical characters are those of chlorite, and which in any case may be regarded as one of those hydrous silicates sometimes termed "viridite."

3. *Limestone of Pole Hill, New Brunswick, and of Llangwyllog in Anglesey.*—In a paper in the Transactions of the Royal Irish Academy, and subsequently in 'Life's Dawn on the Earth,' I noticed a remarkable limestone discovered by Mr. C. Robb, of the Geological Survey, at Pole Hill in New Brunswick, and believed to be of Upper Silurian age. It is composed of fragments of crinoids and shells, the cavities of which are finely injected with a hydrous silicate of alumina, iron, and magnesia, the composition of which, according to Dr. Hunt, approaches to that of the pollyte of Von Kobell, and also to that of a hydrous silicate described by Hoffmann as filling the cavities of specimens of *Eozoon* found in Bohemia. It has also some resemblance to the loganite which mineralizes the *Eozoon* of Burgess, in Canada. At the same time I mentioned a specimen of limestone of similar character which I had found in the McGill-College collection, and which I supposed to be from Wales. It is labelled "Llangolloc," and belonged to the collection of the late Dr. Holmes, of Montreal. Professor Ramsay, to whom I have applied for information as to the locality, kindly informs me that the name is probably "Llangwyllog," that the place so named is in Anglesey, and that limestone of Lower Silurian or Cambrian age occurs in its vicinity.

A portion of this specimen was submitted to Dr. Sterry Hunt, from whose analysis it appears to be of similar character with that of Pole Hill, and like it injects in the most beautiful manner the pores and cavities of crinoids, shells, and corals†. The limestone containing this silicate is of subcrystalline texture, with occasional bright cleavage-faces which belong to crinoidal fragments. Its colour, owing to the included silicate, is dull olive, and it shows occasional small deep green and reddish specks. Its aspect is so waxy, that at a little distance it might be mistaken for an impure serpentine.

When examined with the microscope, the flocculent olive-green silicate is seen to penetrate the mass exactly in the manner of the serpentine in ophiolite, and it has a polariscope appearance approaching to that of serpentine; while greenish by reflected light, it appears reddish when seen in thin slices with transmitted light. It penetrates the finest pores of crinoids, and at the same time fills the cavities of shells and the cells of corals. The larger fillings of this kind give the deep green spots above mentioned, while the red spots are apparently caused by the partial oxidation of the iron of the mineral. In one shell, apparently a small *Orthoceras* or *Theca*, the dark green filling has cracked in the manner of *Septaria*, and the fissures have been filled with carbonate of lime. In some places the mineral has penetrated the pores of shells of Brachiopods or crusts of Trilobites, producing a tubulated appearance not unlike the proper wall of *Eozoon*.

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* Report of Geological Survey of Canada, 1866.

† As the analyses of these specimens by Dr. Hunt have not been published

From the characters of the fragments, I should imagine that this limestone is Lower Silurian rather than Cambrian. It affords an excellent instance of the occurrence of hydrous silicates infiltrating organic fragments, and it deserves the attention of collectors having access to the locality. A curious point of coincidence of this limestone with some of those in the Lower Silurian of Canada is the occurrence of a few bright green specks, probably of apatite or vivianite, giving on a small scale that association of phosphates with hydrous silicates which we find on the great scale in the Laurentian.

The above facts I intend to be supplementary to my papers on *Eozoon* and on the graphite and phosphates of the Laurentian already

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in England, or in such a manner as to be readily compared with each other, I reproduce them here:—

	Pole Hill, New Brunswick.	Llangwyllog, Wales.
Silica	38·93	35·32
Alumina	28·88	22·66
Protoxide of iron	18·86	21·42
Magnesia	4·25	6·98
Potash	1·69	1·49
Soda	0·48	0·67
Water	6·91	11·46
	100·00	100·00

In the Llangwyllog specimen the silicate amounted to three per cent. of the whole, the remainder being carbonate of lime with a very little siliceous sand and fine clay. In the Pole-Hill specimen the silicate amounted to about five per cent., the remainder being limestone with a few quartz grains.

It will be seen that these two silicates, evidently deposited from solution in such a manner as to fill the finest organic pores, are remarkably similar in composition; and the fact that they closely resemble Hoffmann's mineral found in Bohemian *Eozoon*, and also the loganite filling the Burgess *Eozoon* (Quart. Journ. Geol. Soc. vol. xxi. 1865), gives them additional interest.

published in the Journal of this Society, and as illustrative more especially of the affinity of *Eozoon* with its successors in function, the Silurian *Stromatoporæ*, and of the abundant occurrence of serpentine and other hydrous silicates in association with fossils in the Lower Silurian as well as in the older Laurentian.

III. Imitative Forms resembling Eozoon.

It is easy for inexperienced observers to mistake laminated concretions and laminated rocks either for *Stromatopora* or for *Eozoon*, and such misapprehensions are not of unfrequent occurrence. As to concretions, it is only necessary to say that these, when they show concentric layers, are deficient altogether in the primary requirements of laminæ and interspaces; and under the microscope their structures are either merely fragmental, as in ordinary argillaceous and calcareous concretions, or they have radiating crystalline fibres like oolitic grains. Laminated rocks, on the other hand, present alternate layers of different mineral substances, but are destitute of minute structures, and are either parallel to the bedding or to the planes of dykes and igneous masses. In the Montreal mountain there are beautiful examples of a banded dolerite in alternate layers of black pyroxene and white felspar. These occur at the junction of the dolerite with the Silurian limestone through which it has been erupted. Laminated gneissose beds also abound in the Laurentian. Still more remarkable examples are afforded by altered rocks having thin calcite bands, whether arising from deposition or from vein-segregation. One of these now before me is a specimen from the collection of Dr. Newberry, and obtained at Gouverneur, St. Lawrence County, New York. It presents thick bands of a peculiar granitoid rock containing highly crystalline felspar and mica with grains of serpentine; these bands are almost a quarter of an inch in thickness, and are separated by interrupted parallel bands of calcite much thinner than the others. The whole resembles a magnified specimen of *Eozoon*, except in the absence of the connecting chamber-walls and of the characteristic structures. A similar rock has been obtained by Mr. Vennor on the Gatineau; but it is less coarse in texture though equally crystalline, and appears to contain hornblende and pyroxene. These are both Laurentian, and I consider it not impossible that they may have been organic; but they lack the evidence of minute structure, and differ in important details from *Eozoon*. Another specimen from the Horseshoe Mountain in the Western States (I regret that I have mislaid the name of the gentleman to whom I am indebted for this specimen) is a limestone with perfectly regular and uniform layers of minute rhombohedral crystals of dolomite. The layers vary in distance regularly in the thickness of the specimen from two millimetres to one, and must have resulted from the alternate deposition in a very regular manner of dolomite and limestone. These are but a few of the examples of imitative structures which might readily be confounded with *Eozoon*, or which, if resulting from organic growth, have lost all decisive evidence of the fact.

Perhaps still more puzzling imitative forms are those referred to by Hahn, which occur in some felspars, and which I have found in great beauty in certain crystals of orthoclase from Vermont. They are ramifying tubes resembling the canal-system of *Eozoon*, and are evidently a peculiar form of gas-cavities or inclusions. Similar appearances are, however, often presented by the more minute and microscopic varieties of graphic granite, in which the little plates might readily be mistaken, in certain sections, for organic tubulation.

In the present state of knowledge, it is perhaps more excusable to mistake such things for organic structures than to deny the existence of true organic structures because they resemble such forms. Those who have examined moss-agates are familiar with the fact that while some show merely crystals of peroxide of iron or oxide of manganese, others present the forms of *Vaucheriæ* or *Confervæ*. So if one were to place side by side some fibres of asbestos, spicules of *Tethea*, and coniferous wood, preserved, like some from Colorado, as separate white siliceous fibres, they might appear alike; but, even if thoroughly mixed together, the microscope should be able easily to distinguish them. I have specimens of fossil wood, collected by Hartt in Brazil, which have been mineralized by limonite in such a manner that no one, without microscopic examination, could believe them to be other than fibrous brown hæmatite. Such difficulties the micro-geologist must expect to find, and by patient observation to overcome.

EXPLANATION OF THE PLATES.

Plate III.

Fig. 1. Vertical section of *Stromatopora* from the Niagara formation, showing the laminæ and pillars, without supplemental matter, × 20.

2. Vertical section of *Stromatopora* from the Corniferous Limestone, showing pillars ramifying and thickened at the ends, and laminæ without supplemental matter, × 20.

3. Vertical section of *Stromatopora* from the Corniferous Limestone, with much supplemental matter, but showing unthickened laminæ at *a a*, also horizontal canals at *b b*, × 20.

Plate IV.

Fig. 4. Vertical section of *Stromatopora* from the Corniferous Limestone, × 2, showing lines of growth, *a a*; *c*, vertical section of part of the same, × 20; *d*, surface of lamina, × 20, showing solid and hollow pillars.

5. Portion of lamina of another specimen, × 20, showing large pores and bases of two pillars.

6. Portion of another specimen, × 20, showing hollow and solid pillars and a pore at *a*.

7. Portion of silicified *Stromatopora*, weathered, and showing laminæ and pillars in relief, × 20.

8. Portion of *Stromatopora* resting on a tabulate coral and showing acervuline cells at base, × 2.

9. Vertical section of *Caunopora hudsonica*, showing vertical tube and horizontal canals, × 20; *a*, horizontal section of part of the same, showing canals and canaliculi; *b*, vertical section, more magnified.

Plate V.

Fig. 10. Horizontal section of *Caunopora hudsonica*, showing canals radiating from a central tube, × 20.

11. Vertical section of *Cœnostroma nodulata*, Corniferous Limestone, showing canals and concentric laminæ, with much supplemental matter, × 20.

12. Horizontal section of the same, showing large radiating canals, × 20.

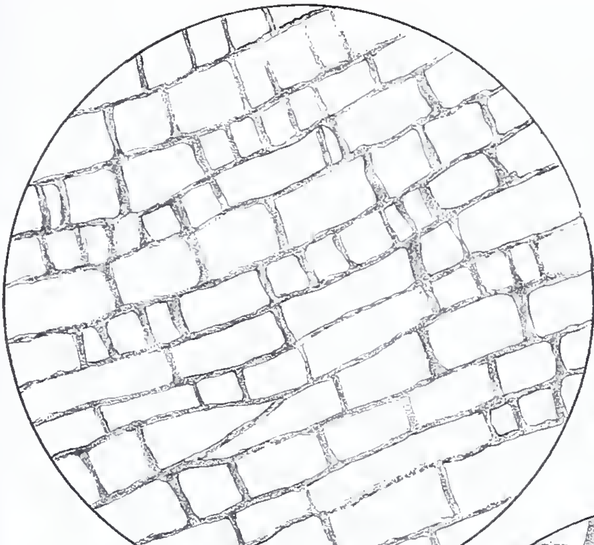
Discussion.

Prof. Duncan expressed his belief that many different forms were united under the one head of *Stromatopora*, and that the confusion was often due to the mode of mineralization. He called attention to a *Smithia* on the table, which, by destructive mineralization, had assumed a deceptive resemblance to *Stromatopora*. He thought this had been the case in some of Mr. Lonsdale's specimens. The tubules in the laminæ of *Stromatopora* certainly had much resemblance to the tubules of *Millepora*. Some of the specimens on the table seemed to have openings like calices; as they opened into the cœnenchyma they could not be corals. The cross tubules excluded them from Polyzoa. They showed no true supplemental skeleton or nummuline layer like *Eozoon*, and so he doubted their Foraminiferal character. With regard to the mineralization, he had some years before received specimens of fossils from Canada, which Dr. Dawson's description had recalled to his mind.

Mr. Champernowne described the tubular structure which he had observed in some of the Stromatoporidæ from Devonshire, both in the horizontal and vertical sections, and felt certain that the group contained many different forms. He had never seen Eozoonal structure in the Devonshire fossils.

Dr. Murie stated that some specimens which he had seen resembled the Hexactinellidæ, and he thought they represented sponges, not precisely Hexactinellids.

1.



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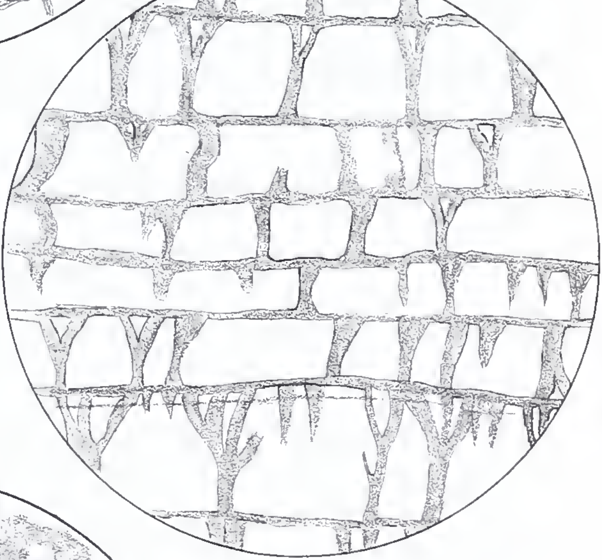
2.



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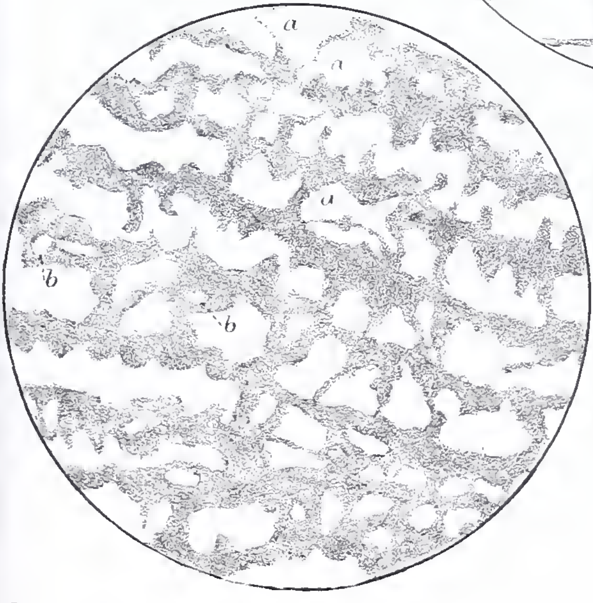


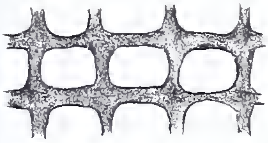
x 20

H Olson lith.

Mintern Bros imp

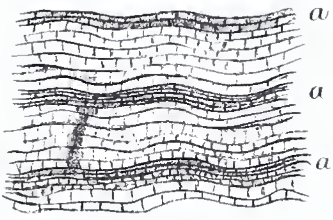
STROMATOPORIDÆ.

4 c.



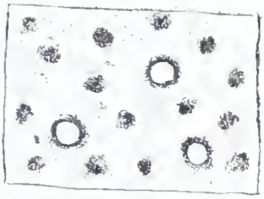
× 20

4.



× 2

4 d.



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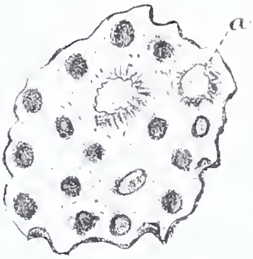
5.



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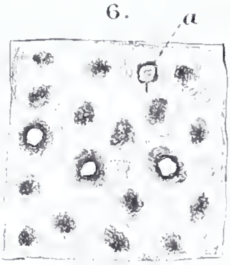
6.



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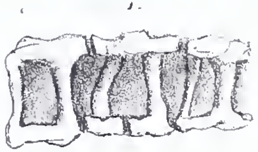

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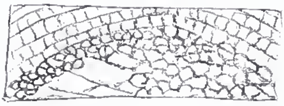
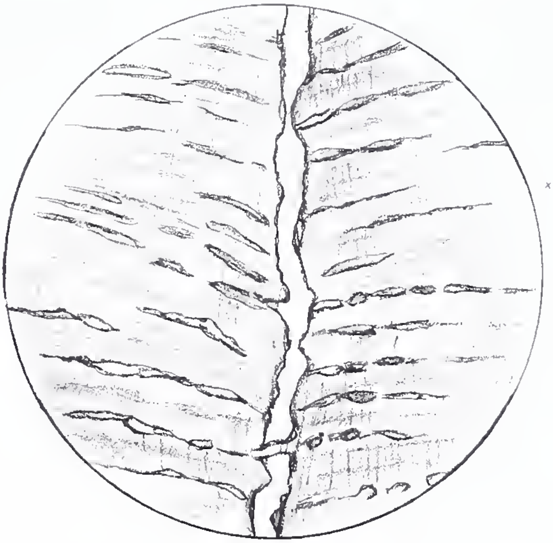
8.



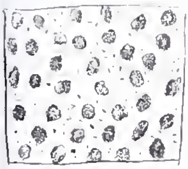
× 2

9.



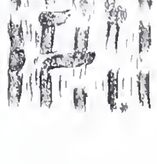
× 20

9a



× 50

9 b.



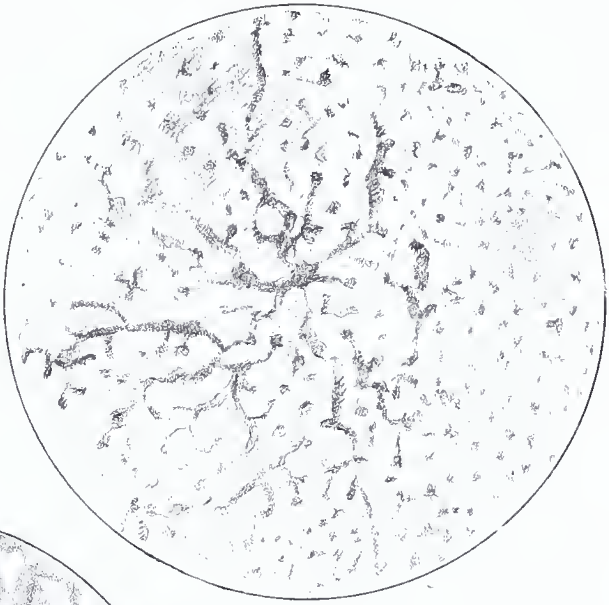
× 50

H Olson lith.

Mintern Bros imp.

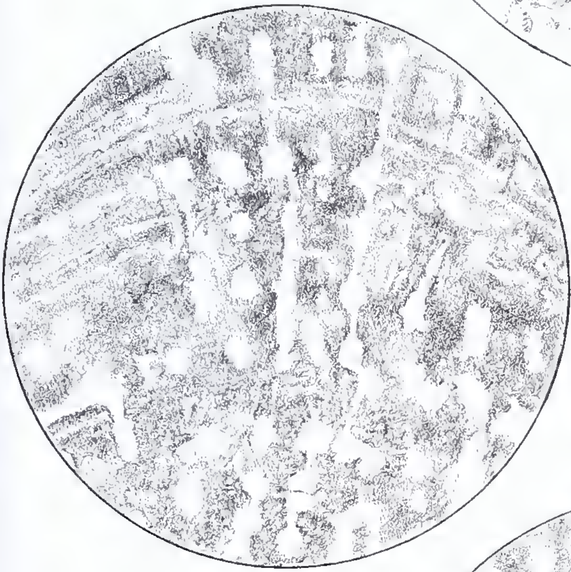
STROMATOPORIDÆ.

10.



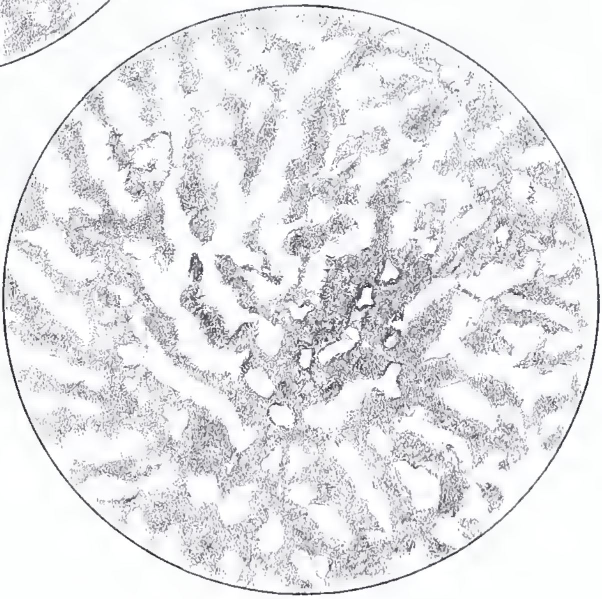
× 20

11.



× 20

12.



× 20

H Olson lith

Mintern Bros imp

STROMATOPORIDÆ.

[*From the* Quarterly Journal *of the* Geological Society *for*
November 1877.]

ON A SPECIMEN OF *DIPLOXYLON* FROM THE COAL-FORMATION OF NOVA SCOTIA.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

Note on a Specimen of Diploxylon from the Coal-formation of Nova Scotia. By J. W. Dawson, LL.D., F.R.S., F.G.S.

In a recent visit to the South Joggins, with the view of further studying the fossils of that district, and more especially of searching for reptilian remains in any erect stumps of *Sigillaria* that might have been exposed by the action of the waves, I was zealously aided by my friend Mr. Albert J. Hill, Manager of the Cumberland Mine*, who, after my departure, determined to take down some erect trees occurring in beds lower in the section than those containing the reptilian remains. In pursuing this investigation he discovered an erect tree twelve feet in height, having the whole of its woody axis perfectly preserved, *in situ*, and showing structure. As this appears to me to be important with reference to questions now in discussion, I beg to present to the Society Mr. Hill's description of the specimen and some remarks on its structure and affinities.

Mr. Hill thus describes the mode of occurrence of the specimen:—

"The tree in question stood partially exposed near the top of a perpendicular cliff, one hundred and twelve feet above the beach (fig. 1). The means of reaching and successfully extracting it from the massive sandstone stratum in which it was still half imbedded, was a problem of no easy solution. The difficulty, however, was overcome by an adventurous workman, who undertook, by means of a ladder attached by a rope to a small tree upon the surface, to descend to a sloping ledge formed by the jutting-out of a coal-seam and superincumbent débris, and to form there a 'standage' from which subsequent operations could be carried on. Having successfully established himself in his eyry, the tree, which, from exposure to the weather and the action of the frost, readily divided itself into sections, was sent up piece by piece in safety to the surface.

"On removing the clay which covered the upper extremity of the stump, I was struck with the unusual appearance of a well-preserved stem or axis in the sandstone cast, and which exhibited structure in a remarkably distinct manner, though here from exposure it had become somewhat friable. Further down, however, it was perfectly calcified and showed its structure distinctly, except in the centre, which was occupied with a core of perfectly cylindrical form and consisting of grey sandstone. The outer surface of the axis is longitudinally striate, without joints, and occupies a position near the side of the cast, from which it is separated throughout by rather more than its own diameter, or about three inches.

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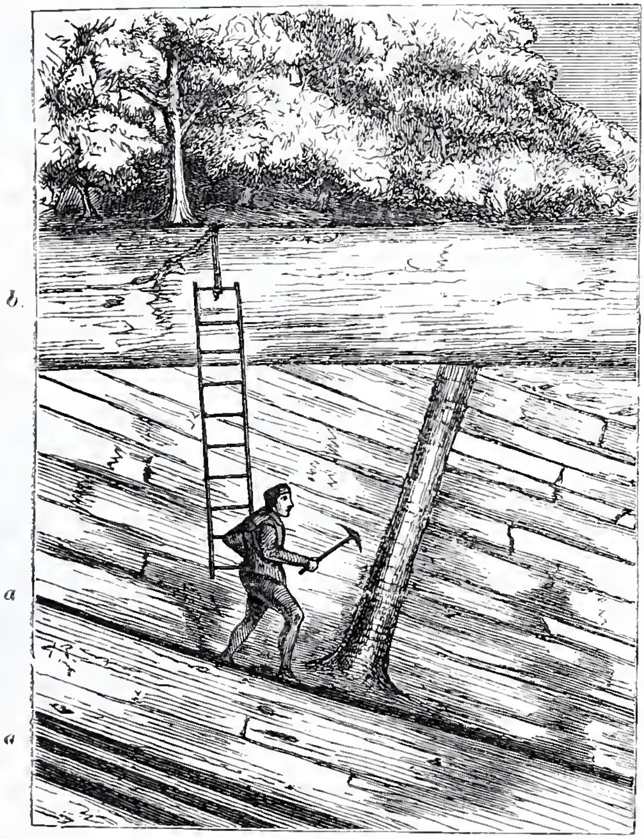
* We were so fortunate as to find an erect *Sigillaria* containing the remains of no less than *thirteen* small batrachians, belonging to six species, two of them new. So soon as these can be worked out from the matrix, I hope to bring them under the notice of this Society.

Fig. 1.—*Surface of the Cliff, showing the position of the Tree.*
(From a sketch by Mr. Albert J. Hill.)



a, a. Coal-seams. *b.* Superficial Drift.

"The stump was found to originate in a six-inch coaly seam, thirty-five feet five inches below that worked in the Cumberland Mine in coal-group 29*a* of Dr. Dawson's section, or division 4, section xi. of Sir W. E. Logan's section*, and separated by an underclay of 3 feet 4 inches from the underlying seam of coarse coal in group 30. The downward termination of the tree exhibited spreading roots, which were, however, in a friable condition and not well preserved, but exhibited on the surface, inside the coaly bark, a fine transverse striation, scarcely visible to the naked eye. The surface-markings of the trunk are also indistinct; but it shows a coarse longitudinal striation and indications of broad flat ribs. The accompanying drawings (figs. 1 and 2) will illustrate the mode of occurrence of the tree in the cliff, and also the principal dimensions of the trunk and axis, with the position of the latter in the cast."

The axis of this remarkable stem is about six centimetres in its greatest diameter, and consists of a central pith cylinder and two concentric coats of scalariform tissue (fig. 3). The pith cylinder is replaced by sandstone, and is about one centimetre in diameter. The inner

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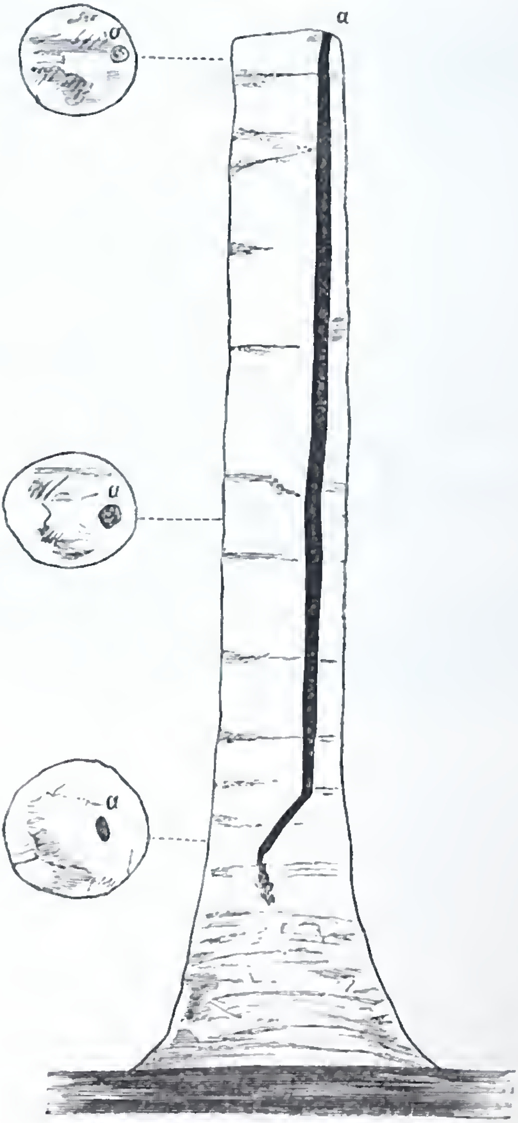
* Acadian Geology, 2nd edition, p. 171.

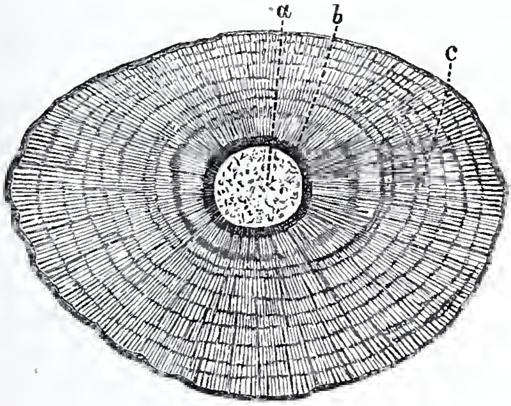
Fig. 2.—*Longitudinal and Transverse Sections of the Trunk, showing the position of the Axis.* (Scale 2½ feet to 1 inch. Drawn by Mr. Hill.)



a, a, a. Internal axis.

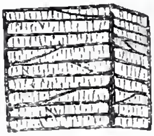
cylinder of scalariform tissue is perfectly continuous, not radiated, and about one millimetre in thickness. Its vessels are somewhat crushed, but have been of large diameter. Its outer surface, which readily separates from that of the outer cylinder, is striated longitudinally. The outer cylinder, which constitutes by much the largest part of the whole, is also composed of scalariform tissue; but this is radially arranged, with the individual cells quadrangular in cross section. The cross bars are similar on all the sides and usually simple and straight, but sometimes branching or slightly reticulated. The wall intervening between the bars has extremely delicate longitudinal waving lines of ligneous lining, in the manner first described by Williamson*, as occurring in the scalariform tissue of certain *Lepidodendra* (fig. 4). A few small radiating spaces, partially occupied with pyrites, obscurely represent the medullary rays, which must have been very feebly developed. The radiating bundles passing to the leaves run nearly horizontally; but their structure is very imperfectly preserved. The stem being old and probably long deprived of its leaves, they may have been partially disorganized before it was fossilized. The outer surface of the axis is striated longitudinally, and in some places marked with impressions of tortuous fibres, apparently those of the inner bark. In the cross section, where weathered, it shows concentric rings; but under the microscope these appear rather as bands of compressed tissue than as proper lines of growth. They are about twenty in number. Though apparently of very lax tissue, the wood of the outer cylinder may, in consequence of the strength of the vertical rods and transverse bars of

Fig. 3.—*Axis of* Diploxylon, *as seen on weathered surface.* (Natural size.)



a. Medullary cylinder, filled with sandstone.
b. Medullary sheath of scalariform tissue.
c. Exogenous cylinder of scalariform tissue, radially arranged and with concentric lines.

Fig. 4.—*Portion of Scalariform Tissue.* (Magnified.)



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* Monthly Microscopical Journal, August 1869.

ligneous lining, have been of considerable firmness, which would, indeed, seem to be implied in the manner of its preservation within the hollow bark.

No trace remains of the thick inner bark, which is represented by sandstone; and, as usual in these trees, the outer bark consists of structureless coal. The outer surface of the sandstone cast shows longitudinal striation; but the ribs, if present, are very indistinct; and only a few somewhat remote and indistinct depressions remain as indications of the leaf-scars. The roots, as stated by Mr. Hill, show a delicate transverse wrinkling, which may be an effect of pressure. In one small portion only could I recognize on them the remains of the stigmarioid areoles.

When treated with an acid, the calcareous matter is removed and the wood remains as a crumbling dark brown mass, which shows the structure very perfectly when diffused in water or Canada balsam. When this brown substance is ignited it burns with scarcely any flame, and leaves a reddish ash, in which the bars of the scalariform tissue are still quite apparent.

In some parts of the axis the medullary cylinder becomes reduced in size, and the inner scalariform cylinder proportionally thickened. Towards the top of the axis there is an indication of bifurcation, which may, however, be a deceptive appearance resulting from mechanical splitting due to decay.

The structures above described are obviously those of *Diploxylon* of Corda; and the tree may be regarded as a *Sigillaria* of this type, the only well-characterized one yet found in the Nova-Scotia coal-field. In comparison with the axes of *Sigillariæ* which I have described in former papers presented to this Society, it agrees in the general arrangement of the tissues, but differs considerably in their character. The pith cylinder is smaller and not Sternbergian. The scalariform tissue of the inner woody cylinder and medullary sheath is much coarser. The outer cylinder, instead of pseudo-scalariform and porous tissue, like that of Cycads, has coarse scalariform tissue. In these respects the trunk resembles those recently described by Williamson*, and is also like specimens from Arran shown to me some years ago by Mr. Carruthers. From the examples given by the former, I cannot doubt that such trees come within the limits of the genus *Sigillaria*, as determined by the markings of the bark; and that they belong to that low type of these trees in which the woody matter, while arranged in an exogenous manner, is wholly scalariform, and with the medullary rays little developed. As Williamson has shown, these trees approach closely to *Lepidodendra* in their structure. On the other hand, the *Sigillariæ* of the type of *S. elegans* of Brongniart, and of *S. spinulosa* of Renault and Grand'-Eury, have a somewhat higher organization, and point to the still more elevated type described by me in 1870. There would thus appear, as I pointed out in my paper on the structures of coal in 1859, and in that on the conditions of accumulation of coal in 1865, and still more fully in that on *Sigillaria* and its allies in 1870*, several distinct types of Sigillarioid trees; though whether we can, as suggested in those papers, separate those with the *Clathraria* and *Favularia* styles of markings from the other *Sigillariæ*, is still doubtful. The French authors above cited regard their *S. elegans* and *S. spinulosa*, which are of the *Favularia* type, as true *Sigillariæ*, and hold that their woody cylinder, with its fibres in radial series and with medullary rays and radiating bundles proceeding from the inner cylinder, allies these trees with the gymnospermous exogens. Williamson regards his *Sigillariæ* of the *Diploxylon* type of structure as probably cryptogamous and allied to *Lepidodendron*, though maintaining that the structure of these stems is truly exogenous. There can scarcely be any doubt that the higher type of *Sigillaria*, which I described in 1870, and which, I think, represents the ordinary coarsely-ribbed species of the type of my *S. Brownii*, are allied to gymnosperms. Prof. Newberry and the writer have adduced strong circumstantial evidence to show that *Sigillariæ* produced the fruits known as *Trigonocarpa*, found so constantly with their remains. Goldenberg, on the other hand, has figured a sort of strobile as attached to *Sigillaria*. Williamson has figured fruit-scars, which he regards as attachments of cones. I have figured† well-preserved fruit-scars of two species which cannot have borne strobiles, but may very probably have borne *Trigonocarpa* or racemes of such fruits. These facts, I think, taken along with those of structure, tend to show that there may be included in the genus *Sigillaria*, as originally founded on the markings of the surface, species widely differing in organization, and of both gymospermous and acrogenous rank. This conclusion is further confirmed by the fact, which I have long ago amply demonstrated in my papers on the structures and mode of accumulation of coal, that in the great coal-beds tissues of gymnospermous character, but distinct from those of Conifers, exist to an enormous amount, while no other trees are found in connexion with these beds to which such tissues can be referred except the *Sigillariæ*.

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* Transactions of the Royal Society.

Should this view be finally established, these trees will present an interesting link of connexion between the gymnosperms and the higher cryptogams. They connect the *Lepidodendra* with the Cycads and Conifers in the gradations of exogenous structure seen in their wood and bark, and also in the remarkable transitions which they exhibit between woody tissues of the discigerous type and those scalariform tissues which, though resembling scalariform vessels properly so called, yet in these plants are evidently arranged in the manner of woody fibres, and take the place of these in the construction of the stem.

The tendency of investigation of late has been to convey the impression that the Sigillarioid and Lepidodendroid trees of the coal-formation were of one somewhat uniform and monotonous type. On the other hand, the great number of species of these trees indicated by external markings, the number of kinds of gymnospermous fruits and cryptogamous strobiles associated with them, and the great range of organization presented by their stems, indicate a considerable variety of generic and specific types, probably bridging over, by means of the class of Gymnosperms, the great gap at present existing between the Angiospermous and Acrogenous trees, and giving an amount of diversity to the forests of the coal-period of which we have as yet little conception. A further illustration of this is presented by the remarkable species of *Cordaites* recently described by M. Grand'Eury, and which furnish another varied series of Gymnospermous type.

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* Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 147.

† Quart. Journ. Geol. Soc. vol. xxii. Report on Fossil Plants of the Lower Carboniferous: 1873.

THE QUEBEC GROUP OF SIR WILLIAM LOGAN.

By J. W. Dawson, LL.D., F.R.S.

Being the Annual Address of the President of the Natural History Society of Montreal, for 1879.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA

The scientific business of the Society in the past winter has included the reading at our monthly meetings of ten papers, comprising a considerable range of subjects. In Geology we have had papers by Dr. Harrington and myself on the mineralogy and mode of occurrence of Apatite; by Dr. Hunt on the various new points which engaged his attention in Europe in the summer of 1878; by Mr. Selwyn and Mr. Macfarlane on the disputed Stratigraphy of Eastern Canada; by Mr. Donald on the remains of a Fossil Elephant; by myself on the Extinct Floras of America. In other departments were Notes on Canadian Ferns by Mr. Goode; on an Esquimaux Bow and Arrow by Mr. Taylor; on the results of an Excursion to St. Jerome by Mr. Marler and Mr. Caulfield; on the Water supply of Montreal by Dr. Baker Edwards.

Of all these subjects that which has perhaps excited the greatest amount of attention, and which best deserves notice here, is the much disputed Geology of the Quebec Group and the associated rocks in the Province of Quebec. This is a subject which has long been in controversy, and which is mixed up with some of the most difficult questions in general geology and in the local structure of the eastern slope of the American continent, both in Canada and the United States. It is a subject on which I have up to the present time avoided any public expression of opinion:—not that I have been indifferent to it—no geologist could be so—nor that I have had no opinions of my own. Having travelled over and examined large portions of the territory occupied by these rocks, it was impossible to avoid arriving at some interpretation of them. But the subject was too intricate to be lightly treated, and others were working at it in detail, and with advantages of public aid which I did not possess. Now, however, it comes up before this Society, introduced in the elaborate and able paper of Mr. Selwyn, followed by the criticisms of Mr. Macfarlane; and these supplemented by Dr. Sterry Hunt's exposition of his own well-known views, in the discussion of Mr. Macfarlane's paper. Farther, in connection with all these various and somewhat discordant opinions, the conclusions arrived at by our late lamented colleague, Sir W. E. Logan, have been canvassed and to some extent set aside.

In these circumstances duty requires that some extended notice of this subject should be taken in this address; and that if no absolutely certain conclusions on all the points in dispute can be affirmed, the state of the controversy should be clearly explained to the bystanders, and the ground cleared for further wrestling on the part of the combatants, should this prove to be necessary. In attempting to perform this somewhat difficult task, it will be proper that I should refrain from entering into details, and that I should confine myself to the question as it relates to Canada, without discussing those features of it which belong to the regions farther south.

I would first say a few words as to the position of the late Sir William E. Logan in relation to the older rocks of Eastern Canada. When Sir William commenced the Geological Survey of Canada in 1842, these rocks, in so far as his field was concerned, were almost a terra incognita, and very scanty means existed for unravelling their complexities. The "Silurian System" of Murchison had been completed in 1838, and in the same year Sedgwick had published his classification of the Cambrian rocks. The earlier final reports of the New York Survey were being issued about the time when Logan commenced his work. The great works of Hall on the Palæontology of New York had not appeared, and scarcely anything was known as to the comparative palæontology and geology of Europe and America. Those who can look back on the crude and chaotic condition of our knowledge at that time, can alone appreciate the magnitude and difficulty of the task that lay before Sir William Logan. To make the matter worse, the most discordant views as to the relative ages of some of the formations in New York and New England which are continuous with those of Eastern Canada, had been maintained by the officers of the New York Survey.

Sir William made early acquaintance with some of these difficult formations. His first summer was spent on the coast of Gaspé and the Baie de Chaleur, where he saw four great formations, the Quebec group, the Upper Silurian, the Devonian, and the Lower Carboniferous, succeeding each other, obviously in ascending order, and each characterized by some fossils, most of which, however, were at that time of very uncertain age. I remember his showing me in the autumn of that year the note-books in which he had carefully sketched the stratigraphical arrangements he had observed, and also the forms of characteristic fossils. But both wanted an interpreter. The plants of the Gaspé Devonian were undescribed; many of them of forms till then unheard of. The shells and corals and graptolites of the older formations could be only roughly correlated with some of those in the New York reports. The rock formations were very unlike those of the New York series. Still this work of 1842 and '43 was plain and easy compared with that which arose in the tracing of these formations to the south-west. I may add here that I have since studied some of these Gaspé sections with Sir William's manuscript note-books in my hand, and have been amazed by the extraordinary care and exactitude with which every feature of the rocks had been observed and noted down. Much of the detail in these early note-books of Sir William, still remains unpublished. Those who would detract from the work of Sir William Logan, if there are any such, should remember these early beginnings, and compare them with the massive foundations which have been laid for us to build upon.

And now, after the labour of more than thirty years on the part of Sir William and those he had gathered around him, how do these subjects stand? (1) We have all the comparatively flat and undisturbed formations of the great plains of Upper and Lower Canada, our share of the interior continental plateau of America, worked out and mapped, and their fossils characterized so that a child may read them. (2) The complex hilly districts with their contorted, disturbed and altered beds, which extend from New England to Gaspé, have been traversed in every direction,* the limits of their different formations marked, and a theory as to their age and structure put forth, which, whether we accept it or not, has in it important features of the truth, and rests on facts on which every disputant must take his stand. (3) We have the still older formations of the Laurentide hills traced in their sinuous windings, and arranged in an order of succession which must stand whether the names given by Sir William, and now accepted throughout the world, be objected to or not. After the work of Sir William Logan, no cavilling as to names can ever deprive Canada of the glory of being the home of the scientific exploration of the Laurentian; and much examination of the ground which he explored enables me to affirm that no one will ever be able permanently to overset the general leading subdivisions which he established in the Laurentian and Huronian systems.

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* The extent of measured and paced sections in these districts by Sir William and Mr. Richardson is almost incredible; and these have been made the basis not only of the geology but of the excellent topographical maps prepared by Mr. Barlow.

Let us turn now to the particular points brought before us in the papers to which reference has been made. It may be well however first to notice some general geological facts which must be present to our minds if we would enter intelligently into these discussions. The formations with which we have to deal in the more ancient geological periods all belong to the bed of the sea. Now in the sea bottom there have been in process of deposition, side by side and contemporaneously, four different kinds of material, differing extremely in their mineral character and in the changes of which they are susceptible. The first of these consists of earthy and fragmental matter washed by water from the surface or sea margins of the land and deposited in belts along coast-lines, or on broader areas where ocean currents have been drifting the detritus ground from the land by ice or washed down by great rivers. The second consists of organic remains of shells, corals and foraminifera, accumulated in coral reefs and the debris washed from them, in shell beds and in the chalky ooze of the deep ocean. Some beds of this kind are very widely distributed. The third is composed of material ejected by igneous action from the interior of the earth and either spread in the manner of lava-flows or of beds of fragments and fine volcanic ash. Such rocks naturally occur in the vicinity of volcanic orifices, which are often disposed in long lines along coasts or crossing ocean basins, but fragmental volcanic matter is often very widely spread by ocean currents and is interstratified with other kinds of aqueous deposit. The fourth and last description of bedded matter is that which is deposited in a crystalline form from solution in water. In later geological times at least, such deposits take place in exceptional circumstances, not of frequent occurrence. Such beds are dolomite, greensand, gypsum, and rock salt.

Now it may be affirmed that at each and every period of the earth's geological history, all or most of these kinds of deposit were in progress locally. But it may also be affirmed that in certain geological periods there was a predominance of one or more over very great areas; and that in any particular area, even of considerable size, there may be definite alternations of these different kinds of material characteristic of particular periods.

Again, along certain lines of the earth's crust, the beds deposited by water have been folded and crushed together, probably by the contraction of the earth's shell in cooling, and along these lines they have been changed, in the way of hardening and becoming crystalline or in being chemically recompounded—alterations which are usually known as metamorphic. But still further, some kinds of deposit are much more liable to such metamorphic changes than others. More especially the beds of igneous origin, from their containing abundance of basic matter, as well as of silica, very readily change under the influence either of heat or water, becoming it may be highly crystalline, or having new mineral substances formed in them by new combinations, or on the other hand, when acted on by water, combining with it and forming hydrous silicates.

One other curious coincidence it is necessary to mention.—It is where the greatest deposits of sediments are going on along coasts or in the course of currents, that crumpling and bending of the crust are most likely to occur, and igneous ejections to be thrown out; and conversely, where igneous ejections are piled up, coasts may be forming or currents deflected, so as to cause at these points the greatest deposit of sediment.

These considerations are sufficient to shew the true value of mineral character, first as a means of distinguishing rocks of different nature and origin, and secondly of separating rocks of different ages within limited localities; with its entire worthlessness when applied to distinguish the ages of beds in widely separated localities. There are in America rocks as widely apart in time as the Huronian of the East and the Carboniferous of the West, which are scarcely distinguishable in mineral character: there are rocks of identical age, as for instance the Lower Silurian of New York and Western Canada and that of Nova Scotia and of Cumberland, which are as unlike in mineral character as it is possible for rocks of the most diverse ages to be.

But can we trust implicitly to stratigraphy? Certainly, when we find one rock directly superimposed on another we know that it is the newer of the two. But when we find old rocks slid over new ones by reversed faults, when we find sharp folds overturning great masses of beds, and when we find portions of beds hardened, altered, and become more resisting, standing up as hills in the midst of the softer materials, perhaps of the same age, which have been swept away from around them, then we have the real difficulties of stratigraphy.

We may have difficulties in fossils as well. Nothing is more common than to find in the modern ocean areas traversed by cold currents which have very different animals living in them from those in the same latitude where the water is warmer. The same thing occurs in older formations. The abundant corals and large shell-fishes in our Montreal limestone of the Trenton age, show a condition of things in which the great area of Central North America was covered with warm waters from the south, teeming with life, and was sheltered from the northern currents of cold and muddy water. But in the Utica shale which succeeds, we have the effect of these cold currents flowing over the same area, loading it with mud, over which lived Graptolites and old fashioned northern Trilobites like *Triarthrus Beckii*, instead of the rich life of the Trenton. This is a mere change to a cold or glacial age.

Now when I inform you that all these causes of error embarrass the study of the Quebec group of Sir William Logan, you will be able to appreciate the difficulties of the case. Crossing the narrow line, a mere crack of the earth's crust, the great reversed fault of Eastern Canada and Lake Champlain, we pass at once from the flat uniform deposits of the great continental plateau of America to entirely different beds, formed at the same time along its Atlantic margin. These beds were affected by volcanic ejections mixing them with ash rocks and causing huge earthquake waves, which tore up the rocks of the sea-bottoms and coasts, and formed great irregular beds of conglomerate, sometimes with boulders many feet in length. In the intervals of these eruptions the area was overflowed by cold Arctic currents carrying sand and mud, sometimes altogether barren of fossils, or again loaded with cold-water creatures like the Graptolites, which occur in vast quantities in some of the beds. Alternating with all this were a few rare lucid intervals, when fossiliferous limestones, just sufficiently like those of the great interior plateau to enable us to guess their similar age, were being produced here and there. Farther, this heap of most irregular and peculiar deposits was that along which subsequent flexures and igneous eruptions and alterations of beds both by heat and heated waters were most rife, all the way down to the Devonian period.

At first the real conditions of this problem were hidden from Sir William Logan, by the error of supposing, with most of the geologists of the United States, that the great reversed fault was a true stratigraphical superposition, and consequently that these strange deposits were newer than those to the west of them. But so soon as the actual nature of the case was made manifest, and this was first due to a right apprehension of the fossils, for which Mr. Billings deserves much of the credit, Sir William at once and for ever apprehended the real conditions of the problem, and set himself to work it out on the true line of investigation.

In evidence of this, and as presenting as clear a view of the whole matter as any we can give, up to the present time, I quote from a note by Sir William appended to Mr. Murray's report on Newfoundland for 1865, and which is less known than his utterances on this subject published in the Canadian reports:

" The sediments which in the first part of the Silurian period were deposited in the ocean surrounding the Laurentian and Huronian nucleus of the present American continent, appear to have differed considerably in different areas. Oscillations in this ancient land permitted to be spread over its surface, when at times submerged, that series of apparently conformable deposits which constitute the New York system, ranging from the Potsdam to the Hudson River formation. But between the Potsdam and Chazy periods, a sudden continental elevation, and subsequent gradual subsidence, allowed the accumulation of a great series of intermediate deposits, which are displayed in the Green Mountains, on one side of the ancient nucleus, and in the metalliferous rocks of Lake Superior, on the other, but which are necessarily absent in the intermediate region of New York and central Canada.

" At an early date in the Silurian period, a great dislocation commenced along the south-eastern line of the ancient gneissic continent, which gave rise to the division that now forms the western and eastern basins. The western basin includes those strata which extended over the surface of the submerged continent, together with the Pre-chazy rocks of Lake Superior, while the Lower Silurian rocks of the eastern basin present only the Pre-chazy formations, unconformably overlaid, in parts, by Upper Silurian and Devonian rocks. The group between the Potsdam and Chazy, in the eastern basin, has been separated into three divisions, but these subdivisions have not yet been defined in the western basin. In the western basin the measures are comparatively flat and undisturbed; while in the eastern they are thrown into innumerable undulations, a vast majority of which present anticlinal forms overturned on the north-western side. The general sinuous north-east and south-west axis of these undulations is parallel with the great dislocation of the St. Lawrence, and the undulations themselves are a part of those belonging to the Appalachian chain of mountains. It is in the western basin that we must look for the more regular succession of the Silurian rocks, from the time of the Chazy, and in the eastern, including Newfoundland, for that of those anterior to it."

In studying these rocks, as Sir William well knew that the great line of disturbance and igneous action lay to the east, as he further knew that in this belt of country rocks all the way up even to the Carboniferous had been profoundly altered, he was not surprised to find that in tracing the Quebec rocks to the south and east, the clay slates, still holding the same fossils, became micaceous or nacreous slates, the bituminous shales graphitic slates, the limestones crystalline marble; and that even serpentine, chloritic slate and hard felspathic rocks appeared to take the place of ordinary aqueous sediments. Consequently he arrived at the large generalizations on the subject embodied in his map of Canada, and to which I believe he adhered to the last.

Was he right in these generalizations? In part, at least, it is certain that he was. I have myself, following in his track, seen distinct Lower Silurian fossils in the nacreous slates and graphitic slates of the Townships, and I have seen these slates alternating with hard quartzites, and felspathic and brecciated rocks, and so far as could be made out by stratigraphy, with chloritic rocks, crystalline dolomite, soapstones and serpentine, these rocks seemingly representing the shales of Point Levis if not still newer members of the series. Dana has recently shown that rocks in Connecticut, usually referred to the Quebec group, or even to the Lower Taconic series of Emmons, and often in a highly crystalline state, actually contain fossils newer than those of the Quebec group, or of Hudson River age.* Murray in Newfoundland has found the most unequivocal superposition of serpentine and chloritic slate on fossiliferous rocks of the Quebec group, and intervening in age between them and the Hudson River group, a point to which we must refer subsequently; and there is nothing incredible or even very unlikely in this. On the other hand, knowing the complexities of all the parts of this troubled sea of eastern palæozoic rocks which I have studied, I cannot deny that there may exist crests of beds older than the Quebec group projecting locally and perhaps largely through these rocks. I am the more inclined to believe this, since there is the best reason to hold that the unaltered members of the Quebec group, as mapped by the Survey on the south shore of the St. Lawrence. include beds ranging all the way from the Lower Cambrian up to the Chazy. Similar, perhaps older, beds, no doubt exist largely, mixed with igneous outflows and breccias, in the hills of the interior.

But if any man thinks proper to put down a hard and fast line on the map of Eastern Canada, and to maintain that all the crystalline rocks which apparently project through and rise above the Quebec group, are of greater age, I must decline to go with him in this assertion, since I feel certain that such an extreme view cannot be in accordance with facts. No one, however, I feel persuaded, will now go so far as this; but I believe the pendulum has already swung farther than it should in this direction. and must go back again nearer to Sir William Logan's position. Facts in support of this conclusion rise before my mind as I write, and may be brought forward on some future occasion, but they would involve a series of papers for their full elucidation.

We have had presented to us ably and well by Mr. Selwyn, Mr. Macfarlane, and Dr. Hunt, conclusions differing more or less widely from those of Sir William, and from each other. There are no doubt important elements of truth in them all, but when these are fully and fairly sifted, the unprejudiced geologist will conclude that while they may modify the results of Sir William's work, they by no means overthrow them; and that we are still a long way from the solution in all their details of the problems which occupied Sir William to the last, and which he left only partially solved.

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* American Journal of Science, May, 1879. One of the fossils recognized by Dana seems to be the *Stromatopora compacta* of Billings. really a *Stenopora*, known in Canada both below and above the Levis,

We may now sum this matter up, in so far as Sir William Logan's work is concerned, and that of Richardson as his assistant, and of Hall and Billings in the department of Palæontology. Their researches have established:—(1) The general diversity of mineral character in the Palæozoic sediments on the Atlantic slope as compared with the internal plateau of Canada. In those results Bailey, Matthew, and Hartt in New Brunswick, and the writer in Nova Scotia, have also borne some part. (2) The establishment of the Quebec group of rocks as a series equivalent in age to the Calciferous of America, and to the Arenig and Skiddaw of England, and the elucidation of its peculiar fauna. (3) The tracing out and definition of the peculiar faulted junction of the coastal series with that of the interior plateau, extending from Quebec to Lake Champlain. (4) The definition in connection with the rocks of the Quebec group, by fossils and stratigraphy, of formations extending in age from the Potsdam sandstone to the Upper Silurian, as in contact with this group, in various relations, along its range from the American frontier to Gaspé; but the complexities in connection with these various points of contact and the doubts attending the ages of the several formations have never yet been fully solved in their details. (5) The identification of the members of the Quebec group and associated formations with their geological equivalents in districts where these had assumed different mineral conditions, either from the association of contemporaneous igneous beds and masses, or from subsequent alteration or both. It is with reference to the results under this head, the most difficult of all, that the greater part of the objections to Sir William's views have arisen.

Let us now shortly examine Mr. Selwyn's new results, with reference to these conclusions, especially to the last.

The first point deserving of notice here is the inability of Mr. Selwyn to recognize in the extension of the Quebec group eastward and westward of Quebec, those subdivisions which have been named the Levis, Lauzon, and Sillery. Originally Sir William recognized two divisions only, the Levis and Sillery. Subsequently he introduced, on the ground merely of convenience, the intermediate Lauzon; though apparently not regarding the threefold division as at all important, but merely as provisional*

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* Report of 1866, p. 4.

Of those subdivisions the most important is the Levis, which forms the fossiliferous and most readily recognized horizon of the Quebec group. About the precise base of this division. held to be the lowest of the group, there is some uncertainty, Sir William has referred to it as resting on Potsdam rocks in the vicinity of Lake Champlain, and farther east on older shales and limestones; and Mr. Richardson has endeavoured to separate from it certain sandstones and associated beds on the Lower St. Lawrence. More especially I may refer to the sandstones and shales near Metis, holding *Astropolithon*, *Scolithus*, and *Arenicolites spiralis*, and to beds near Matane holding species of *Conocephalites* of very primitive type. In Newfoundland also, where the sequence of these beds is better seen than elsewhere, there are, according to Richardson and Billings, 2000 feet of beds under the typical Levis and over the Lower Calciferous, holding fossils unquestionably of the second fauna of Barrande, or Lower Silurian, and below them there is a great thickness of Calciferous and Potsdam. All these beds must exist in the Quebec group districts of Canada, folded up along with the Levis, and as yet very imperfectly separated from it, nor is it at all unlikely that in some localities they may have been confounded with the Lauzon and Sillery.

With regard to the distinction of these last-named formations as upper members of the Quebec group, we must agree with Mr. Selwyn that in the present state of our knowledge they cannot be clearly separated from the Levis or from one another. Nevertheless it is true that on the typical Levis there rest sandstones and shales of considerable thickness, not holding its characteristic fossils, and forming an upper member of the Quebec group, as yet not well defined, but representing in nature the Lauzon and Sillery of Logan.

In the next place, Mr. Selwyn is disposed to separate from the Quebec group the greater part of those altered and crystalline rocks associated with it, and which appeared to Sir William Logan to be metamorphosed equivalents of this group, and largely of its upper or Sillery division. Of these rocks he forms two series, which however he regards as closely associated, and probably not unconformable with each other.

The first and nearest in age to the Quebec group is defined as including "felspathic, chloritic, epidotic and quartzose sandstones, red, gray and greenish siliceous slates and argillites," with "breccias and agglomerates, diorites, dolerites, and amygdaloids," as well as serpentine, dolomite, and calcite. In short this formation is one of mixed igneous and aqueous origin, non-fossiliferous, except in the case of a few microscopic fragments, and mostly crystalline. As regarded by Sir W. E. Logan, these rocks, in consequence of their apparent conformity with the Levis series, and their apparent superposition in some sections, were held to be an upper member of the Quebec group, and were mapped as Sillery. They were thus placed in the same position with the serpentine and chloritic formation of Newfoundland, as described by Murray, with the Cobequid series as I have described it in Nova Scotia,* and with the Borrowdale igneous rocks resting on the English equivalents of the Levis beds as defined by Ward in Cumberland.

Mr. Selwyn, on the other hand, thinks that the main mass of these peculiar rocks either comes out unconformably from beneath the Levis series or is separated from it by a fault, and is in all probability older, though the obscure traces of fossils found in some of the beds would indicate that they are not older in any case than Lower Silurian or Upper Cambrian.

It is obvious that with reference to a formation so greatly disturbed, either of these theoretical views may be correct, or that there may be two crystalline series, one below and another above the Levis beds. Where I have had opportunity to observe the formation, at Melbourne, and in a few other places, I have seen no reason to dissent from Sir W. E. Logan's view; but at that time Mr. Selwyn's explanation was not before my mind, nor have I examined the sections on which he chiefly relies.

Had Sir W. E. Logan lived, it was his intention to have, at his own cost, bored through the crystalline rocks at some selected site, in order to obtain positive proof of the subterposition of the Levis beds. This expense is not now likely to be incurred, but the whole question will in course of time be settled by the careful re-examination and mapping, which now that these new views have been suggested by the head of the Geological Survey, the district is likely to receive.

Mr. Selwyn's third division, supposed to be still older, possibly Lower Cambrian, in some respects resembles the second, but is predominently slaty and quartzose, though still with dolomites and other magnesian rocks. These would naturally fall into the place assigned to them, if the age attributed to the second series be admitted, otherwise they come into the period of the Sillery, or some newer formation, in an altered condition. I do not know that fossils have been found in these rocks, within the limits of Canada at least, but if they are really of Cambrian age, the richness of this fauna elsewhere in N. E. America would warrant the hope that the age assigned to them may be indicated by fossils, while, if like some similar beds to the southward, they hold Silurian species, these also must in some places be recognizable; so that if they finally fail to afford fossil remains or yield Lower Cambrian species, this, with their mineral character and apparent distribution, would sustain Mr. Selwyn's view; while, on the other hand, the discovery of a few distinctive Silurian forms might suffice to overturn it.

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* Acadian Geology, third edition.

It would appear that the third and second series of Mr. Selwyn, above mentioned, are the same with the rocks which in Hitchcock's map of New Hampshire are named Montalban and Huronian. The former term has however been applied by Dr. Hunt to a series newer than the Huronian, and possibly of Lower Cambrian age, so that if it is correctly used by Hitchcock, his so-called Huronian may be in reality Upper Cambrian or Lower Silurian. It is to be deprecated as not conducive to correct conclusions, that terms of this kind should be used to represent merely mineral resemblances, irrespective of those evidences of geological age derived from stratigraphy and fossils. It is due here to Dr. Hunt to explain that he has for many years on independent grounds regarded the beds of Mr. Selwyn's second and third groups as, for the most part at least, Huronian in age, and a similar conclusion was also arrived at from comparison with the older formations of Scandinavia, by Mr. Macfarlane. Thus in one way or another all these gentlemen dissent from Sir William's conclusions, while also differing from each other, a sufficient evidence of the complicated character of the problem with which he had to deal, and whose ultimate solution may embrace elements of all the generalizations which have been put forth.

Some suggestions may at least be offered toward the solution of these questions which deserve the attention of those who have been occupied with them. The first is that we should accustom ourselves to the anticipation that contemporaneous palæozoic rocks in the regions of the western lakes, of the plains of Ontario and Quebec, and of the eastern slope, are not likely to be identical in mineral character. Farther, that even in the central of these three regions we may expect differences in approaching certain parts of the older rocks. At Murray Bay, for example, on the border of the Laurentian, we find the Black River limestones in great part represented by coarse sandstones, and we find similar changes in the Chazy near Grenville. A third suggestion is, that in order to understand the eastern members of the Lower Silurian, it is necessary to be acquainted with the contemporaneous igneous ejections mixed with these rocks, and if possible to distinguish them from those of similar character so largely present in the Huronian. This I have attempted, though with only partial success, to effect for the Acadian Provinces. Another, to which Dr. Hunt has directed attention in his recent report in connection with the Survey of Pennsylvania, is the importance of inquiry as to which of the many successive movements and plications of the earth's crust occurring in palæozoic time, have most seriously affected the now so greatly plicated and disturbed rocks of the Quebec group. Still another, and one of the most important, is the study of the various kinds of alteration which these rocks have undergone. We have in eastern Canada rocks as young as the Devonian which have been sensibly affected in this way, and there can be no doubt that large areas of the Quebec group have suffered similar changes, and that on the one hand it is possible that these metamorphosed portions have been confounded with older series, or that on the other these older series have been inadvertently mixed with them.

The value to be attached to fossils is another point of much importance. Long experience has convinced me that in the Cambrian and Silurian ages this kind of evidence is the most conclusive of all; but then it must be rightly understood. As already observed. we must discriminate the animals characteristic of the cold Atlantic waters loaded with Arctic sediment, from those of the sheltered continental plateau. We must also bear in mind that oceanic and probably floating forms of low grade, like the Graptolites, have an enormous range in time, as compared, for example, with the Trilobites, and the same remark applies to some mollusks proper to sandy or muddy bottoms, like the Lingulae and their allies, as compared with other mollusca.

All these precautions must be taken in the study of these rocks, and it involves no depreciation of the geologists abovementioned, to say that the different conclusions at which they have arrived, depend very much on the different degrees of importance which they have attached to the various kinds of evidence accessible.

One word, before closing, respecting names. These are of little importance in themselves, but it is of consequence that they should not be needlessly changed, and that they should not be misapplied.

The name "Quebec Group," introduced by Sir William Logan, should be retained for that peculiar development of the rocks of the second fauna, eminently exposed and accessible in the vicinity of Quebec, to whatever extent its extensions east and west may be circumscribed; and whatever value may be attached to the local subdivisions into Levis, Lauzon and Sillery. On the one hand, the use of one of these terms, Levis, for the whole, leads to misconception; and the absurdity of the term "Canadian" (applied in one widely-known text book to the rocks of this age) becomes apparent when we see it made correlative with a purely local name like "Trenton," and when we consider that Canada is a region greater than the United States of America, and with equally varied geological structure.

The more recent developments in the geology of North America require, as Dr. Hunt and Mr. Selwyn have urged, that the Cambrian system should be recognized as a group altogether distinct from the Silurian; and whatever views as to the use of these names may ultimately prevail in England, for us the dividing line between the Cambrian and the Siluro-Cambrian or Lower Silurian, unquestionably comes about the horizon of the Potsdam. As to the formations older than the Cambrian, I am disposed to regard the Montalban and Taconian of Dr. Hunt as representing definite groups of rocks, which may however eventually prove to belong to the base of the Cambrian, with which equivalent strata in the Maritime Provinces of Canada seem to be associated. The Huronian series of Logan represents another great fact in the geology of North America, namely a period of immense igneous ejection and disturbance intervening between the Laurentian and the Cambrian. In the typical Huronian area of Lake Huron it unquestionably rests unconformably on the Laurentian, and is itself overlaid by rocks of Cambrian or still greater age. It has precisely the same mineral characters and position as far east as New Brunswick and Newfoundland, and as far west as the Pacific slope,[*] and is thus one of the most widely diffused of American formations, though I believe it has locally been confounded with rocks of similar mineral character but of newer date. The upper Laurentian of Logan, the Norian of Hunt, is entirely different in mineral character from the Huronian, and stratigraphically is related to the Middle Laurentian rather than to the Huronian, notwithstanding local unconformity. The Lower Laurentian of Logan may now, since the explorations of Vennor,[†] be safely divided into a lower and middle group, the former being however nothing more than the great gneissic formation recognized by Logan as the Trembling Mountain gneiss, which forms the base of his well-known Laurentian section, and the Bojian gneiss of European observers. The idea that the Middle Laurentian, the horizon of Eozoon Canadense and of the great Phosphate and Graphite deposits, is identical with the Hastings group, or with the Huronian, has, I am fully convinced, after some study of the Lake Huron, Madoc and St. John exposures of these formations, no foundation in fact. There seems, however, good reason to believe that the gap between the Lower Laurentian of Lake Huron and the Huronian, is to be filled not merely by the Middle Laurentian and the Norian, but by such rocks as those described by Dr. Bigsby, Prof. Bell and Dr. G. M. Dawson on the Lake of the Woods and other regions west and north of Lake Superior, and at present included in the Huronian, to the base of which many of them no doubt belong.[‡]

I should not have occupied your time so long with these matters, but for their great importance geologically, and the able papers in which they have been brought under our notice, and for the circumstance that I have been renewing my studies of these rocks, in the hope of contributing some notes on Sir William Logan's share in their investigation, to a biographical sketch of that eminent geologist now in progress under the care of our associate, Dr. Harrington, to whom it has been committed by Sir William's executors.

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[*] Clarence King's Report of the 40th Parallel. The rugged features and precipitous sides of the Laurentian and Huronian exposures in this region correspond with Logan's view of the steep slope of the Laurentian land at the time of the deposition of the Quebec Group rocks.

[†] Reports Geological Survey of Canada.

[‡] G. M. Dawson's Report on 49th Parallel. Bell, Reports Geological Survey of Canada.

[*From the* Quarterly Journal *of the* Geological Society *for May* 1882.]

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

Notes *on* Prototaxites and Pachytheca *discovered by* Dr. Hicks *in the* Denbighshire Grits *of* Corwen, N. Wales. By Principal Dawson, LL.D., F.R.S., &c., M'Gill College, Montreal.

Specimens of the first-mentioned fossil were kindly sent to me by Dr. Hicks, at my request, but unfortunately arrived when I was at my summer residence at Little Metis. Though without the means of examining them microscopically, I ventured to write, after studying them with a good pocket-lens, that they resembled *Prototaxites*, and could not be referred to Algæ. The latter conclusion might appear rash; but there are, to the practised eye, indications in specimens of this kind which can scarcely deceive. The fibrous and highly carbonaceous nature of the darker specimens, and the silky and incoherent texture of the lighter-coloured ones, are characters never found in any fossil plants except those having durable woody tissues. Further, the occurrence of the material in angular fragments and in a condition approaching to that of the mineral charcoal of the Coal-measures, proves subaerial decay, little likely to have occurred in the case of aquatic plants. From the state of preservation of the specimens, I also inferred that, if really of the nature of *Prototaxites*, they might throw some additional light on its structure, as the specimens previously studied had been from entire trunks in a silicified state.

On my return to town, I found awaiting me the Journal of the Geological Society containing Dr. Hicks's paper; and the figures there given showed at once the correctness of the reference made by Mr. Etheridge of the plant to *Prototaxites*, and its close resemblance to *P. Logani*[*], except in the appearance of bifurcating fibres, a character which I have not observed, and which may be merely an error in observation or in drawing.

Portions of the specimens sent by Dr. Hicks were at once prepared, not only by slicing but by treatment with boiling nitric acid, and by diffusion of the more lax fibres in water and in Canada balsam. On examination they gave the results stated below.

In state of preservation the two kinds of specimens examined are somewhat different. The dark variety has the long cells or woody fibres filled with rods of transparent siliceous matter, and the walls are represented by a thick structureless layer of carbon, which often shows angular cracks, such as appear in the walls of thick-walled woody fibres when carbonized. These cracks are sometimes transverse, giving a scalariform appearance, but they do not represent a true structure. The internal siliceous casts, when bared by nitric acid of their carbonaceous coating, show here and there transverse or spiral markings, produced by the projection of the ligneous lining on the inner side of the cells. There is no trace of the intercellular flocculent matter produced by decay of the outer surfaces of the cells or their connecting tissue, such as I have described in the silicified trunks of *Prototaxites*.

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[*] Report on Devonian Plants of Canada, 1871, pl. ii.

The lighter-coloured variety has probably been originally preserved in a similar manner; but the woody envelope of the fibres has been entirely removed, leaving only the siliceous internal casts, which are so lax that they can be scraped into water and viewed as transparent objects without slicing. This is precisely the state of the asbestos-like silicified Coniferous wood found in the gold gravels of California. These rod-like siliceous casts preserve on their surfaces distinct traces of the irregularly spiral ligneous lining of the perished cell-wall. A few of them also show rounded bodies of brownish colour in their interior. These may be ferruginous concretions, but are possibly granules of resinous matter, in which case such tubes may represent resin-cells.

In all the above particulars these specimens confirm my original determination of the woody character of *Prototaxites*, to which genus they undoubtedly belong. They differ, however, from *P. Logani* in the smaller diameter of the fibres, and in the ligneous lining, which presents the appearance of interrupted transverse bands rather than regular spirals. These characters would seem to indicate a distinct species, which may therefore be named *P. Hicksii*, in honour of its discoverer*. I may recall here a statement made in my report on the Devonian plants of Canada, that in 1870, when Mr. Etheridge was so kind as to permit me to examine the slabs in the Jermyn-Street Museum, with *Pachytheca* of Hooker from the Ludlow, I recognized, associated with this, fragments of wood having the structure of *Prototaxites*. The similar association in Dr. Hicks's specimens and the peculiar fibrous structure of the walls of *Pachytheca*, as figured by Mr. Etheridge, may well excite the suspicion that these bodies are connected with *Prototaxites*, especially as similar round bodies are seen in beds holding this fossil in Canada, though without distinct structure. In this connexion it is to be observed that the bodies in question are probably seeds rather than spore-cases, and that they have the structure of *Ætheotesta*, to which, in a recent paper in the Journal of the Geological Society†, I have referred a similar seed, found in the Devonian of Scotland.

With reference to the affinities of *Prototaxites*, I have not made the crude assertion attributed to me, that this plant "belonged to Taxineæ." I merely compared its structure to the lax spiral fibre of some Taxine trees, and especially to certain Taxine woods fossilized after long immersion in water, with which we are familiar in the Tertiary formations. This was all that was intended by the name *Prototaxites*, except to suggest that this plant was one of the prototypal gymnosperms of the Palæozoic period. Further, in consequence of its upper limit in Canada being apparently the Lower Devonian, where it comes into contact with the wood of the earliest species of *Dadoxylon*, I have conjectured that it would be found in much older formations*, and am therefore not surprised to find this conjecture realized by the discovery of Dr. Hicks.

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* Instead of *Nematophycus Hicksii*, as proposed by Mr. Etheridge.

† Vol. xxxvii. p. 306, pl. xii. fig. 14.

In the specimen sent to me there appears, besides the fragments of *Prototaxites* and a few rounded impressions probably of *Pachytheca*, a fragment of the rhizoma of *Psilophyton* and portions of epidermal tissue. The state of preservation of these bears additional testimony to the woody and durable texture of *Prototaxites*. Still further, in recent explorations in the Bay de Chaleur, I have found in the Lower Devonian silicified trunks of *Prototaxites* two feet and a half in diameter; and these lie in beds abounding in entire specimens of *Psilophyton*, some of them apparently in the place of their growth, and in a formation which contains only land plants, associated in some layers with remains of fishes and of bivalve Crustaceans, minute Gasteropods, and *Spirorbis*, the whole much resembling the coal-formation in its mineral character and grouping of fossils. The idea that *Prototaxites* may have affinities with Algæ has been sufficiently disposed of in my communication to the 'Monthly Microscopical Journal' in 1873; and the characters and state of preservation of Dr. Hicks's specimens fully confirm the reasoning in that paper. The large specimens recently obtained at the Bay de Chaleur also enable me to reaffirm the existence of a dense coaly bark at the surface of these trees. Some of them show on their weathered ends evidence of remarkably regular exogenous rings, extending from the surface nearly to the centre. There may, however, have been an internal axis or medulla, different from the outer structure; and this I hope to be able to ascertain by series of slices from the centre to the circumference of the trunk.

I have lately had a number of slices made of the large silicified trunks found last summer near Campbellton, New Brunswick. They present appearances of a very peculiar and interesting character. In the better-preserved specimens the large cylindrical fibres are filled with rows of rounded concretions of silica, often enclosing limpid hexagonal crystals. In many cases they present the most deceptive resemblance to the bordered pores of coniferous wood, and in other modes of occurrence might be mistaken for spores of some parasitic fungus. Under polarized light, however, they are seen to be merely crystalline and concretionary; and when the fibres show their true structure, this is reticulated or spiral, as in the ordinary specimens of *Prototaxites*. In many parts of these specimens, however, the formation of granular crystals of quartz has completely disorganized the structure. I have referred to concretionary appearances of the kind above described, in my "Report on the Devonian Plants of Canada," as occurring in the Gaspé specimens of *Prototaxites*; but they are coarser and less beautiful than in those from Campbellton.

It is possible that these appearances may throw some light on the globular bodies observed in the cells of the Welsh specimens of *Prototaxites* and *Pachytheca*, though I cannot certainly affirm that the latter are concretionary and not structural.

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* Report on Devonian Plants.

I have sent a fragment of the Campbellton *Prototaxites* to Mr. Carruthers, and have no doubt that, if sliced, it will show the peculiar state of mineralization above described.

Mr. Hicks having been so kind as to send me a specimen of the *Pachytheca* from Corwen, I have compared it with Mr. Etheridge's figures and description, and with similar objects from this country and elsewhere. Mr. Etheridge's figures very accurately represent the specimen examined by me; but I would make the following additional remarks. The specimen is globular, but slightly flattened in the plane of the bed. It is three millimetres in diameter, and consists of an internal globular nucleus of granular texture, rather more than one millimetre in diameter, surrounded by a thick testa or outer envelope of radiating fibres. The fibrous part is in the same state of preservation as one of the kinds of associated fossil wood, the walls of the fibres being carbonized and the cavities filled with transparent silica. Under high powers the "spore-like bodies" referred to by Mr. Etheridge resolve themselves into alternate swellings and contractions of the cavities of certain of the fibres, others presenting a more uniform cylindrical form. The latter occasionally show the irregular transverse bands observed in the wood of *Prototaxites* from the same locality. The internal nucleus is apparently wholly granular, as if it had been composed of parenchymatous tissue.

There are in my cabinet specimens of similar bodies in a pyritized state, from the Upper Silurian (Lower Helderberg) of Cape Bon Ami, in New Brunswick, where they are found associated with fragments of wood of *Prototaxites*. Though on the whole less perfectly preserved, as to structure, than the Welsh specimens, when sliced in certain directions they present traces of a micropyle and embryo, and are, in my judgment, true seeds.

There seems little doubt that these New Brunswick specimens and those from Corwen may be referred to Brongniart's genus *Ætheotesta*, and that they are nearly allied to my *Ætheotesta devonica* from the Devonian of Scotland (discovered by Rev. Thomas Brown, of Edinburgh). In connexion with the structures observed in the Corwen specimens, it is worthy of note that Brongniart says of his species *Æ. subglobosa*, from the coal-formation, that the testa is "thick, homogeneous, formed of fibres or elongated cells perpendicular to the surface. *These fibres appear, in one specimen, to be intermixed with little globular cells*, possibly in consequence of alteration of the tissue"*. This is precisely the appearance presented by the testa of *Pachytheca*. Brongniart's *Ætheotesta* is undoubtedly a seed, and he compares it with the nut-like seeds of Taxineæ.

Pachytheca has now been found associated with *Prototaxites*, not only at Corwen, but also in the Upper Ludlow of England, in the Upper Silurian of Cape Bon Ami, and in the Lower Devonian of Bordeaux Quarry opposite Campbellton in New Brunswick; and since the structure of the Corwen specimen corresponds with that of *Pro-*

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* Annales des Sciences, tome xx. série 5.

totaxites, tho presumption becomes strong that the connexion is not accidental. Under these circumstances, and considering the Taxine affinities of *Ætheotesta*, it would seem that *Pachytheca* may be accepted as affording some corroboration of the gymnospermous nature of *Prototaxites**.

Dr. Hicks has also sent a specimen of the so-called "microspores" found with *Pachytheca*. They occur in this specimen in a little semicircular patch or group, and are represented by mere impressions without any trace of organic matter. The lobed or furrowed appearance which they present gives to some of them the aspect of tetraspores enclosed in mother-cells, like the "*Triplosporites*" of Brown, in which case they might, as suggested by Mr. Carruthers, be Lycopodiaceous; but theso furrows are so irregular that they may be accidental wrinkles. The occurrence of these objects in patches or groups suggests affinities with the *Parka decipiens*† of Fleming, a Devonian fossil at one time believed to be vegetable, but moro recently referred to ova of Crustaceans. Similar groups of small rounded bodies occur in the Devonian of Gaspé; but I have not been able to decide as to their nature.

DISCUSSION.

The PRESIDENT referred to the wide interest which the discoveries of Dr. Hicks had evidently excited.

Mr. CARRUTHERS referred to a specimen sent to him by Dr. Dawson, which had its structure beautifully exhibited externally from weathering, and which he hoped to study by means of sections. He thought that Dr. Dawson's ideas were the result of having examined the specimens by imperfect means. He insisted that the minute structure of these plants was quite different from that of Conifers. The stems are made up of interlacing tubes; the smaller, which crossed the larger obliquely, were not spiral fibres inside wood-cells as supposed by Dr. Dawson. He thought no one acquainted with the minute structures of Coniferous wood and of Algæ could be led to accept the views of Dr. Dawson. The pseudo-exogenous structure is found in some living Algæ, as in *Laminaria*. With respect to *Pachytheca* he had always experienced great difficulty at arriving at any conclusion. Ho thought that Sir Joseph Hooker was justified in referring it to Lycopodiaceæ from the materials at his command. He had long known that *Pachytheca* had a cellular structure filling its interior, consisting of tubular cells like those of the wall, but matted together. He was inclined to doubt whether they are really vegetable, and may not be animal remains. Mr. Storrie, of Cardiff, had sent him, years ago, well-preserved and beautifully prepared sections of *Pachytheca* showing the whole from centre to circumference; these led him to doubt their vegetable origin. He wished that zoologists would examine *Pachytheca*. He was satisfied, from the specimens on the table exhibited by Dr. Sterry Hunt, that the *Eopteris* of Saporta is really not a plant but a crystallization of pyrites, as suggested by M. Meunier-Chalmas.

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* It occurs to me to add here that the beds in which *Prototaxites* is met with, in Gaspé and near Campbellton, contain no marine remains, but only land-plants; and though it would appear that in the Corwen beds the plants are associated with marine remains, yet the nature of the specimens sent to me is evidently of littoral rather than deep-sea character, and here also they are associated with land vegetation. These modes of occurrence, as I have elsewhere pointed out, are not in harmony with the supposition that in these plants we have to deal with great oceanic Algæ. Nor does this supposition accord with the fact that the wood of *Prototaxites* retains its form and is silicified in beds in which herbaceous land-plants are perfectly flattened.

† Lyell, 'Student's Elements,' p. 444; Nicholson, 'Palæontology,' vol. i. p. 382 (Dr. Hicks has, I see, made the same suggestions in his "Additional Notes," Quart. Journ. Geol. Soc., Feb. 1882).

Dr. DUNCAN remarked upon the wonderful discrepancies of opinion that prevailed. He did not regard the central part of *Pachytheca* as a mycelium. He regarded it as the float or conceptacle of a seaweed.

Prof. JUDD stated that he exhibited, on behalf of Mr. THISELTON DYER, two sections of *Pachytheca*. Mr. Thiselton Dyer regretted that he was unable to be present at the Meeting, but had sent Prof. Judd a letter, from which he read the following extract:—

"Kew,
November 15, 1881.

"I have to thank you for drawing my attention to the paper and discussion in the August number of the Quarterly Journal. Having read this, I venture to think that the specimens which I am placing in your hands my be found of some importance if exhibited at the meeting.

"Their history is briefly this. Some time ago Sir Joseph Hooker received from Mr. Grindrod a number of specimens of *Pachytheca in situ* on pieces of rock. As these examples of the fossils were apparently well preserved, two or three were detached and intrusted to Mr. Norman, who made the sections which are now in your hands. Sir Joseph Hooker did not see his way to any definite conclusion as regards the structure which they exhibited. He, however, allowed me to examine them, and they have since remained in my possession. The conclusion which I arrived at was that their structure agreed, in general plan, with that of *Codium*, as shown in Kützing, 'Phycologia Generalis,' pl. 42. f. 1.

"As a possible algal nature has been suggested for *Pachytheca* by Mr. Etheridge, I think it may not be considered presumptuous on my part to now state that I have been of opinion, ever since I studied the sections, that *Prototaxites* and *Pachytheca* are both referable to the same morphological type of structure. The radiating cells in the latter terminate internally in loosely interlacing slender filaments, with which the central cavity has been apparently filled. *Pachytheca* does not resemble any type of sporangium with which I am acquainted; the structure, as displayed in the specimens, has a certain resemblance to that of the sporocarp of *Pilularia*; but I cannot reconcile what I have seen of it with the supposition that it was a reproductive structure belonging to any type of vascular cryptogam.

"According to the view which I take of *Pachytheca,* it was an algal organism, closely resembling in essential structure a diminutive *Codium*, but with the peripheral cells branched instead of simple. I do not see any evidence to lead me to suppose that it was related to *Prototaxites* as a sporangial organ. The existence of *Prototaxites* on modern biological views necessarily implies the existence, at some time or other, of allied forms; and I do not see why *Pachytheca* should not have been a contemporaneous one."

Dr. HICKS explained the way in which the specimens had come into Principal Dawson's hands.

The PRESIDENT supported Mr. Carruthers's views as to the non-coniferous character of *Nematophycus*. With regard to *Pachytheca* he felt great doubts.

[*Extracted from the* Geological Magazine, Decade II. Vol. X.
No. 3, p. 111, March, 1883.]

CANADIAN PLEISTOCENE.

By J. W. Dawson, LL.D., F.R.S., etc., etc.

REFERENCE is sometimes made, in the course of the active discussion of the Glacial age in the Geological Magazine, to the Pleistocene of Canada, a country which, perhaps, as much as any other, in its great extent from the Atlantic to the Pacific, and from latitude 45° to the Arctic Sea, affords opportunities for the study of the deposits of this period. It has occurred to me, in connexion with this, that it might be useful to your readers to present to them a short summary of Canadian facts, as I think I have established them in publications on this subject, which are, perhaps, better known in this country than in England.

In the St. Lawrence Valley, which may be regarded as a typical region, these deposits may be tabulated as follows, in ascending order :[1]—

(*a*) Peaty beds under Boulder-clay. (*b*) Lower stratified sands and gravels (Syrtensian deposits of Matthew).	These represent land surfaces and sea and coast areas immediately anterior to the Boulder-clay.
(*c*) Boulder-clay or Till; hard clay, or unstratified sand, with boulders, local and travelled, and stones often striated and polished.	The Lower St. Lawrence region holds a few marine shells of Arctic species. Farther inland is non-fossiliferous, but has usually the chemical characters of a marine deposit.
(*d*) Lower Leda clay; fine clay, often laminated, and with a few large travelled boulders, probably equivalent to Erie clay[2] of inland districts.	Holds *Leda* (*Portlandia*) *arctica*, and sometimes *Tellina groenlandica ;* and seems to have been deposited in very cold and ice-laden water.
(*e*) Upper Leda clay, and probably Sangeen clay[2] of inland districts; clay and sandy clay, in the Lower St. Lawrence, with numerous marine shells.	Holds in Eastern Canada a marine fauna identical with that of the northern part of the Gulf of St. Lawrence at present; and locally affords remains of a boreal flora.
(*f*) Saxicava sand and gravel, often with numerous travelled boulders (Upper Boulder deposit), probably the same with Algoma sand, etc., of the West.	Shallow-water fauna of boreal character, more especially *Saxicava rugosa* and its varieties. Bones of Whales, etc.
(*g*) Post-Glacial deposits, river alluvia and gravels, Peaty deposits, Lake bottoms, etc.	Remains of *Mastodon* and *Elephas*, modern fresh-water shells.

The Lower Boulder-clay (*c*) is often a true and very hard Till, resting on intensely glaciated rock-surfaces, and filled with stones and boulders. Where very thick, it can be seen to have a rude stratification. Even when destitute of marine fossils, it shows its submarine accumulation by the unoxidized and unweathered condition of its materials. The striæ beneath it, and the direction of transport of its boulders, show a general movement from N.E. to S.W., or up the St. Lawrence Valley from the Atlantic. Connected with it, and apparently of the same age, are evidences of local glaciers denuding into the valley from the Lawrentian highlands. The Boulder-clay of the basins of the great lakes, and of the western plains, and of the Missouri Coteau and its northern extensions, seems to be of similar character. The basins of the lakes are parts of old Pliocene valleys dammed up with Pleistocene debris.[1] The Missouri Coteau and its extensions, probably the greatest moraine in the world, and the "terminal moraine" of the great continental glaciers of some American geologists, appears to be the deposit at the margin of a sea laden with vast fields of floating ice.[2]

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[1] Supplement to Acadian Geology, 1878. Notes on Post-Pliocene of Canada, Canadian Naturalist, vol. vi. 1871. [2] Geology of Canada, 1863.

The Lower Leda Clay (*d*) seems in all respects similar to the deposits now forming under the ice in Baffin's Bay and the Spitzbergen Sea. The Upper Leda Clay represents a considerable amelioration of climate, its fauna being so similar to that of the Gulf of St. Lawrence at present that I have dredged in a living state nearly all the species it contains, off the coasts on which it occurs. Land plants found in the beds holding these marine shells are of species still living on the north shore of the St. Lawrence, and show that there were in certain portions of this period considerable land surfaces clothed with vegetation. The Upper Leda Clay is probably contemporaneous with the so-called inter-glacial deposits holding plants and insects discovered by Hinde on the shores of Lake Ontario.[3] On the Ottawa it contains land plants of modern Canadian species, insects and feathers of birds, intermixed with skeletons of Capelin and shells living in the Gulf of St. Lawrence.

The changes of level in the course of the deposition of the Leda Clays must have been very great; fossiliferous marine deposits of this age being found at a height of at least 600 feet, and sea-beaches at a much greater elevation, while at other times there must have been large land areas and even fresh-water lakes. Littoral gravels and sands of this period may also be undistinguishable, except by their greater elevation, from those of the Saxicava sand. I have recently described the bones of a large whale (*Megaptera longimana*) from gravel north of the outlet of Lake Ontario and 420 feet above the level of the sea, which is not improbably contemporaneous with the Leda Clay of lower levels, and much higher than deposits near Lake Ontario regarded as of lacustrine origin.[4] These changes of the relative levels of sea and land must be taken into account in explaining the distribution of marine clays and sands, boulder deposits, etc., which are often regarded with reference to the present levels of the country, or as contemporaneous deposits without regard to their elevation, a method certain to lead to inaccurate conclusions.

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[1] Newberry, Reports on Ohio; Hunt, Canadian Reports; Spencer, Ancient Outlet of Lake Erie, Ann. Phil. Society, 1881.

[2] Report on 49th Parallel, G. M. Dawson.

[3] Proceedings of Canadian Institute, 1877. Dr. Hinde in this paper incorrectly states that the Leda Clay belongs to the "close of the Glacial Period," and that boulder drift is not found above it. In truth, as Admiral Bayfield, Sir Charles Lyell, and the writer have shown, boulder-drift is still in progress in the Gulf and River St. Lawrence, though in a more limited area than in the Post-Pliocene period; but any considerable subsidence of the land might enable it to resume its former extension.

[4] Canadian Naturalist, vol. x. No. 7.

The Saxicava Sand (*f*) indicates shallow-water conditions with much driftage of boulders, and probably glaciers on the mountains. It constitutes in many districts a second boulder formation, and possibly implies a somewhat more severe or at least more extreme climate than that of the Upper Leda Clay. Terraces along the coast mark the successive stages of elevation of the land in and after this period. There is also evidence of a greater elevation of the land succeeding the time of the Saxicava Sand, and preceding the modern era.[1]

It is well known that very diverse theoretical views exist among geologists as to the origin of the deposits above referred to. The conclusions which have been forced upon the writer by detailed studies extending over the last forty years, are that in Canada the condition of most extreme glaciation was one of partial submergence, in which the valleys were occupied by a sea laden with heavy field ice continuing throughout the summer, while the hills remaining above water were occupied with glaciers, and that these conditions varied in their distribution with the varying levels of the land, giving rise to great local diversities, as well as to changes of climate. There seems to be within the limits of Canada no good evidence of a general covering of the land with a thick mantle of ice, though there must at certain periods have been very extensive glaciers on the Laurentian axis and in the mountainous regions of the west.[2] It does not, indeed, seem possible that, under any conceivable meteorological conditions, an area so extensive as that of Canada, if existing as a land surface, should receive, except on its oceanic margins, a sufficient amount of precipitation to produce a continental glacier.

Details on some of the above-mentioned formations will be found in my "Notes on the Post-Pliocene of Canada," and a large amount of recent information exists in the Reports of the Geological Surveys of Canada, and in papers published in the Canadian Naturalist and Geologist.

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[1] Supplement to Acadian Geology, 3rd edition, pp. 14, et seq.

[2] G. M. Dawson, Reports on British Columbia, and Superficial Geology of British Columbia, Journal Geol. Society, 1878.

STEPHEN AUSTIN AND SONS, PRINTERS, HERTFORD.

[*Extracted from the* Geological Magazine, Decade II. Vol. X.
No. 3, p. 111, March, 1883.]

Canadian Pleistocene.

By J. W. Dawson, LL.D., F.R.S., etc., etc.

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In the St. Lawrence Valley, which may be regarded as a typical region, these deposits may be tabulated as follows, in ascending order:[1]—

(*a*) Peaty beds under Boulder-clay. (*b*) Lower stratified sands and gravels (Syrtensian deposits of Matthew).	These represent land surfaces and sea and coast areas immediately anterior to the Boulder-clay.
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u glaciers de[illegible]ling into the valley from the Lawrentian highlands. The Boulder-clay of the basins of the great lakes, and of the western plains, and of the Missouri Coteau and its northern extensions, seems to be of similar character. The basins of the lakes are parts of old Pliocene valleys dammed up with Pleistocene debris.[1] The Missouri Coteau and its extensions, probably the greatest moraine in the world, and the "terminal moraine" of the great continental glacier of some American geologists, appears to be the deposit at the margin of a sea laden with vast fields of floating ice.[2]

The Lower Leda Clay *(d)* seems in all respects similar to the deposits now forming under the ice in Baffin's Bay and the Spitzbergen Sea. The Upper Leda Clay represents a considerable amelioration of climate, its fauna being so similar to that of the Gulf of St. Lawrence at present, that I have dredged in a living state nearly all the species it contains, off the coasts on which it occurs. Land plants found in the beds holding these marine shells are of species still living on the north shore of the St. Lawrence, and show that there were in certain portions of this period considerable land surfaces clothed with vegetation. The Upper Leda Clay is probably contemporaneous with the so-called inter-glacial deposits holding plants and insects discovered by Hinde on the shores of Lake Ontario.[3] On the Ottawa it contains land plants of modern Canadian species, insects and feathers of birds, intermixed with skeletons of of Capelin and shells living in the Gulf of St. Lawrence.

The changes of level in the course of the deposition of the Leda Clays must have been very great; fossiliferous marine deposits of this age being found at a height of at least 600 feet, and sea-beaches at a much greater elevation, while at other times there must have been large land areas and even fresh-water lakes. Littoral gravels and sands of this period may also be undistinguishable, except by their greater elevation, from those of the Saxicava sand. I have recently described the bones of a large whale (*Megaptera longimana*) from gravel north of the outlet of Lake Ontario and 420 feet above the level of the sea, which is not improbably contemporaneous with the Leda Clay of lower levels, and much higher than deposits near Lake Ontario regarded as of lacustrine origin.[4] These changes of the relative levels of sea and land must be taken into account in explaining the distribution of marine clays and sands, boulder deposits, etc., which are often regarded with reference to the present levels of the country, or as contemporaneous deposits without regard to their elevation, a method certain to lead to inaccurate conclusions.

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[1] Newberry, Reports on Ohio; Hunt, Canadian Reports; Spencer, Ancient Outlet of Lake Erie, Ann. Phil. Society, 1881.

[2] Report on 49th Parallel, G. M. Dawson.

[3] Proceedings of Canadian Institute, 1877. Dr. Hinde in this paper incorrectly states that the Leda Clay belongs to the "close of the Glacial Period," and that boulder drift is not found above it. In truth, as Admiral Bayfield, Sir Charles Lyell, and the writer have shown, boulder-drift is still in progress in the Gulf and River St. Lawrence, though in a more limited area than in the Post-Pliocene period; but any considerable subsidence of the land might enable it to resume its former extension.

[4] Canadian Naturalist, vol. x. No. 7.

The Saxicava Sand (*f*) indicates shallow-water conditions with much driftage of boulders, and probably glaciers on the mountains. It constitutes in many districts a second boulder formation, and possibly implies a somewhat more severe or at least more extreme climate than that of the Upper Leda Clay. Terraces along the coast mark the successive stages of elevation of the land in and after this period. There is also evidence of a greater elevation of the land succeeding the time of the Saxicava Sand, and preceding the modern era.[1]

It is well known that very diverse theoretical views exist among geologists as to the origin of the deposits above referred to. The conclusions which have been forced upon the writer by detailed studies extending over the last forty years, are that in Canada the condition of most extreme glaciation was one of partial submergence, in which the valleys were occupied by a sea laden with heavy field ice continuing throughout the summer, while the hills remaining above water were occupied with glaciers, and that these conditions varied in their distribution with the varying levels of the land, giving rise to great local diversities, as well as to changes of climate. There seems to be within the limits of Canada no good evidence of a general covering of the land with a thick mantle of ice, though there must at certain periods have been very extensive glaciers on the Laurentian axis and in the mountainous regions of the west.[2] It does not, indeed, seem possible that, under any conceivable meteorological conditions, an area so extensive as that of Canada, if existing as a land surface, should receive, except on its oceanic margins, a sufficient amount of precipitation to produce a continental glacier.

Details on some of the above-mentioned formations will be found in my "Notes on the Post-Pliocene of Canada," and a large amount of recent information exists in the Reports of the Geological Surveys of Canada, and in papers published in the Canadian Naturalist and Geologist.

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[1] Supplement to Acadian Geology, 3rd edition, pp. 14, et seq.

[2] G. M. Dawson, Reports on British Columbia, and Superficial Geology of British Columbia, Journal Geol. Society, 1878.

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SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

THE EARTHQUAKE

OF OCTOBER 20TH, 1870

By Principal Dawson, LL.D., F.R.S., &c.

One of the uses of this Journal is to record, in a permanent manner, any rare or unusual natural phenomena, the notices of which, in the daily and weekly press, would soon perish. This function the *Naturalist* has hitherto performed with respect to Earthquakes. In our number for October, 1860, a detailed account was given of the Earthquake of the 17th of that month, which, in many respects, resembled that of this year.

In connection with that event, a general notice of the received theories of Earthquakes was given, and also a catalogue of all the previously recorded Earthquakes felt in Eastern America, about 87 in number, of which at last 29 were felt in Canada, more or less severely—by far the most violent having apparently been that of February 5th, 1663.* The next earthquake of any importance was that of April, 1864, a detailed notice of which will be found in the *Naturalist*, Vol. 1., N.S,. p. 156.

The following extracts from newspapers show the intensity of the shock, and, approximately, its time at different places, arranged in the order of their longitudes.

Frederickton, N. B. — Shock felt at 11.45.

Bic. — An earthquake was sensibly felt here at 11.30 this morning, lasting half a minute. The direction seems to be from West to East.

River du Loup, *en bas*, 11.13. — The shock commenced and lasted 45 seconds; appeared to come from N. W.; accompanied by rather heavy rumbling.

Point Levi, 11.15. — A dreadful shock of earthquake was felt here at 11.15.

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*Canadian Naturalist, 1st Series, Vol. V. p. 363.

Quebec.—At 11.17 a.m. a severe shock of earthquake was felt here. Buildings shook and bells rang; several chimneys were knocked down in Desfosses street, and two persons nearly killed.

Boston.—A shock of earthquake was felt here and all along the line from Montreal.

The Earthquake.—Inverness, P. Q., Oct. 20th.—A severe shock of earthquake was felt here to day at about 11.25 a.m., which lasted for over a minute. The course of the undulation seemed to be in an easterly direction. It caused great alarm in this vicinity.

Sherbooke.—Felt earthquake here at 11.25. Shook the office books off the table, and the clock down.

Richmond, 11.17 a.m.—A severe shock just felt here. Buildings at station rocked a good deal.

Durham, P. Q., Oct. 20.—A slight shock of an earthquake passed here about 11.15 a.m., moving north. It shook the houses quite perceptibly, and lasted several moments.

Three Rivers, 11.25.—A very severe earthquake has been experienced in this city. The vibrations were very severe, lasting several minutes. The people ran out of their houses.

Nicolet.—A violent earthquake was felt here at 11.19. The whole building tottered, as if about falling. It lasted about 20 seconds.

Berthier.—We had an earthquake very strong in Berthier at half-past eleven to-day.

Sorel, 11.14 a.m.—A shock of earthquake was distinctly felt here, of nearly a minute duration.

St. Hyacinthe.—A strong shock of earthquake was felt here at 11.15, lasting about thirty seconds.

Waterloo Village, P. Q., Oct. 20th.—The shock of an earthquake was felt here at 11.30 to-day; duration about fifty seconds. It commenced with a low rumbling noise. Buildings shook and trembled, and people rushed out of their houses terrified.

Rouse's Point, 11.20.—Severe shock of earthquake here. The Railroad depot shook very much.

St. John's P. Q.—Quite a severe shock of earthquake at 11.15.

Montreal.—The shock was felt at Quebec about 30 seconds before it reached here. The operator at Quebec was just in the act of asking his *confrere* of Montreal if any shock was felt, when wall and instrument began to rock and shake.

ALBANY.—Not felt within 16 miles from here. Felt in Schenectady, N. Y., Cambridge, N. Y., and Cooper's Town, N. Y.

NEW YORK.—A severe shock of earthquake was felt in this city this morning about 11 o'clock. Shocks were also felt in Schenectady, N. Y., Cleveland, O., Boston, Burlington, Vt., Portland, Me., Troy, Saratoga, Warrensburg and Warsaw, N. Y.

ST. ANDREWS.—Shock of earthquake this morning; lasted 30 seconds.

L'ORIGNAL, 11.15.—We felt a very severe shock of earthquake, which lasted about half a minute. It shook the Court House in which the telegraph office is.

COTEAU LANDING.—Severe shock of earthquake this morning; shook buildings.

OTTAWA, Oct. 20.—A strong shock of earthquake here this forenoon. Drizzling rain and cold.

ST. CATHERINES.—A shock of earthquake felt here.

OWEN SOUND, Oct. 20.—A shock of earthquake was felt here this morning, commencing at 10.52, and lasted about 3 minutes.

In several places it is noticed that the shock was much more severe on sandy and loose ground than on solid rock. This is an ordinary occurrence, depending on the rapid and unobstructed passage of the vibrations through solid rock. This same cause no doubt accounts for the circumstance that at some places the shock was not felt at all, while in others not far distant it was felt severely.

The following notice sent to one of the newspapers by Mr. Bennetts, of the Capel Mine, is curious, as in other cases such shocks are often felt severely in mines; but the rapid or vertical transmission of the shock may account for it in connection, perhaps, with the direction of the vein and of the workings.—"At this mine the shock of the earthquake was very plainly felt at the surface; but at the time of its occurence I was some 200 feet underground and neither the miners, of whom there were about twenty, nor myself, felt the shock or noticed anything unusual. Could it be ascertained, it would be interesting to know to what extent other mines were affected by such an unusual occurrence."

On the other hand I am informed by Mr. James Douglas, of Quebec, that in the Harvey Hill Mine, in rock not dissimilar from that at the Capel Mine, and in the same region, though more to the eastward, the shock was sufficiently violent to throw down masses of rock, and greatly to terrify the miners, then at work in the mine.

In a notice contributed to Silliman's Journal, for November, by Prof. Newton, it is stated that the first shock began at New Haven, at 11h. 19.m 45s. A.M., New Haven mean time. "It lasted 10 seconds, and its individual vibrations were about two thirds of a second in duration, or one and one third of a second for a complete double vibration. The second series of vibrations occurred after an interval of 5 seconds, and lasted 11 seconds.

The direction of vibration was NNE and SSW. It was felt at Boston a minute and three quarters before reaching New Haven. At Cleveland, Ohio, it was felt at the same time as at New Haven. "Slight vibrations were felt as far south as Richmond, Va., and as far west as Dubuque, Iowa." Prof. Bell, of the Geological Survey, informs me that the shock was felt at Sault St. Marie, and on the North Shore of Lake Superior, and was accompanied by a cracking or rending sound in the rocks.

The following account of the Meteorological Phenomena, attending the earthquake at Montreal, is contributed by Dr. Smallwood of the McGill College observatory.

"Rain fell on the 13th day, followed by a rise in the Barometer, and a splendid display of the Aurora Borealis on the night of the 14th day. Numerous and very large spots were present on the solar disc, which had been the case for some considerable time, more especially during the presence of the Aurora on the nights of the 23rd, 24th, 25th, and 26th days of last month (September.)

"The maximum reading of the Barometer at 7 a. m. on the morning of the 16th day, indicated 30.215 inches, and was succeeded by a very fine, warm day, the mean temperature of which was 63.9 degrees, wind S. W. Showers of rain fell on the 17th from 10 a. m. till 3 p. m., with a west wind and with a falling Barometer, which at 9 p. m. of that day stood at 30.000 inches. From 1 a. m. of the 18th (Tuesday) a very rapid and sudden fall was observed, viz: 0.639 of an inch in six hours, and it attained its minimum, 29.361 inches, at 7 a. m. on that day.

"From that hour a gradual and somewhat sudden rise took place accompanied by a very heavy gale of wind. The clouds were passing from the West, but the wind veered to all points of the compass. The register of the Anemometer at the Observatory shows a complete disc of concentric circles, with a velocity varying from 35 to 15 miles per hour.

" There was also a rise of 0.507 of an inch in the Barometer, with a falling temperature. Frost occurred during the night, and a good breeze continued from the West. The Thermometer at 7 a. m. showed 33.1 degrees, and the Barometer 30.070 inches.

" From this time the temperature rose and the Barometer fell, and this morning at 7 a. m., stood at 29.499 inches. Rain set in during the night, and at 7 o'clock 0.214 of an inch had fallen. Thermometer 42 degrees. Wind S. W. Mean velocity, 3.14 miles per hour.

" At 11 h. 17 m. Montreal mean time, a very considerable shock of an earthquake was felt generally throughout the city; the first series of vibrations lasted for from 10 to 15 seconds, and was succeeded by a slight interval of a few seconds, when a second shock occurred, of less duration and of less intensity, lasting from 5 to 8 seconds. No wave of sound was perceptible, and the wave of motion was undulating and in a straight line (rectilinear) and of considerable relaxation. Domestic articles rocked to and fro, but no damage to buildings has resulted.

" The magnets were very seriously affected at 10.30.

" The barometer continued to fall after the first shock. At 2 p. m. it stood at 29.299 inches; thermometer 44.8 degrees; wind S. W., with rain. Professor Kingston telegraphed me that the magnets at the Toronto Observatory showed slight shocks at 10 minutes to 11."

" As usual with Canadian earthquakes, this was felt most severely on the Lower St. Lawrence, more especially at the junction of the Lower Silurian and Laurentian formations in the vicinity of Bay St. Paul, Murray Bay, and the Saguenay. The following graphic account is given by Rev. Mr. Plamondon, Parish Priest of Bay St. Paul, in a letter to " *L'Evenement*."

" Un mot à la hâte pour vous faire connaître les désastres causés, tout à coup ici et dans les environs, par le tremblement de terre le plus étrange qui soit arrivé de mémoire d'hommes. Environ une demi-heure avant midi, un coup de foudre (c'est la seule dénomination que je puisse lui donner) une énorme détonation a jeté tout le monde dans la stupeur et la terre s'est mise non

a trembler, mais à bouillonner de manière à donner le vertige, non-seulement à tous ceux qui étaient dans les maisons, mais encore à ceux qui étaient en plein air. Toutes les habitations semblaient être sur un volcan, et la terre se fendillant en cinq ou six endroits, lançait des colonnes d'eau à six, huit et peut-être quinze pieds en l'air, entraînant après elles une quantité de sable qui s'est étendu sur le sol. Presque toutes les cheminées se sont écroulées, de sorte que je ne pense pas qu'il en soit resté six debout dans tout le village. Des pans de maisons se sont abattus, et ici et là les poëles, meubles et autres objets ont été renversés, emportant avec eux les ustensiles, la vaisselle, etc.

" Notre couvent, qui était sous la direction des bonnes sœurs de la Congrégation est inhabitable pour le moment, trois cheminées et le plafond des mansardes étant démolis en partie. Trois élèves et une servante de cet établissement on été blessées par des pierres provenant de l'éboulement des cheminées: cependant aucune d'elles n'est gravement atteinte.

" L'église a beaucoup souffert ; une partie de son portail s'est écroulée, emportant un morçeau de la voûte, et le reste des murs est tellement lésardé qu'il est douteux qu'on puisse les réparer.

" La stupeur a été telle que pendant les trois ou quatre minutes qu'a duré la secousse, tout le monde pensait que c'en était fini, et que nous allions tous périr. Nous sommes encore sur le qui vive ; car de temps en temps de légères secousses se font encore sentir. Chacun redoute la nuit prochaine et se demande où il sera demain matin. Il est certain que si cette catastrophe fut arrivée pendant la nuit, nous aurions à déplorer la perte d'un grand nombre de vies.

" Il nous est venu des gens de diverses concessions, de sorte que nous avons des nouvelles d'un circuit d'environ quatre lieues et nulle part il n'est resté une habitation intacte, partout la secousse a été aussi violente. A l'heure où j'écris ces lignes, la terre tremble encore, et qui sait si je pourrai terminer. Aussi veuillez excuser le décousu de ces quelques détails que je vous donne à la hâte, ainsi que les fautes qui peuvent s'y être glissées."

Other correspondents mention the opening of chasms in the ground, from which streams of water and sand burst forth. This phenomenon arises from the landslips produced in the terraces of Post-pliocene clay which in that part of the country rest against the steep sides of the Laurentian hills. These are ready to slide downward with any slight movement of the earth, and to press the

water out of the sandy layers associated with them. or give outlet to hidden springs and streams.

It is also stated, that a mass of rock 400 feet in length fell from the face of the cliff, at Cape Trinity, in the Saguenay. Cape Trinity is a cliff of Laurentian gneiss, presenting to the river a vertical front about 1500 feet high.

It will be observed that the earthquake of Oct. 20th extended over 25 degrees of longitude, from the Bay of Fundy westward, and over at least 12 degrees of latitude from the North Shore of the St. Lawrence, southward. Its extension to the northward into Rupert's Land, is not yet known.

The general direction of the vibration, as shown by the times at the different places mentioned above, and by observations of Prof. Winslow, at Cambridge, and by Mr. Douglas, at Quebec, was from north east to south west. The shock must therefore have been propagated from the Laurentian regions north of the St. Lawrence, into the Silurian and later formations to the southward. This is of interest in connection with the facts already related as to its severity at the edge of the Laurentian formation at Bay St. Paul, and elsewhere.

It is also deserving of notice, that at Bay St. Paul and Les Eboulements several shocks are recorded; and that additional shocks are stated to have occurred at the latter place on the 26th October, six days after the principal shock.

It has been observed on previous occasions that the Barometer is low at the time of the occurrence of earthquakes, in Eastern America. Dr. Smallwood, has kindly furnished the following table in illustration of this. It gives the state of the Barometer at Montreal, on the days of eleven of the most recent earthquakes felt here.

Date of Earthquake.	Barometer.
1855. Feb. 8	29.806
— — 19	29.800
1856. Jan. 1	30.163
1857. Oct. 16	29.308
1858. Jan. 15	30.292
— May 10	29.800
— June 27	29.800
1860. Oct. 17	29.964
1864. Apr. 20	29.900
1870. Mar. 4	30.300
1870. Oct. 20	29.299

It will be observed that the Barometer was unusually low on the day of the late earthquake, and according to information kindly sent to Dr. Smallwood from the observatory at Washington, this was very general over the continent.

It is thus extremely probable, that, whatever the primary cause of the movement, its occurrence on the particular day in question, may have been determined by this removal of pressure from the surface of the land. It is further to be observed, that this would place the phenomena in harmony with that general cause to which the frequent small earthquakes on the Eastern Coast of America, were formerly assigned by the writer, namely the removal of material from the land, and its accumulation on the banks off the American Coast, producing unequal pressure and consequent tension of the earth's crust, and this connected with the ascertained slow subsidence of the coast, and perhaps with slight elevation of the interior of the continent.

In a notice of the earthquake in *Silliman's Journal*, for January, 1871, by Mr. A. C. Twining, the following statement occurs with reference to the intensity of the shocks at Bay St. Paul and Les Eboulements—" They are in general conformity to what has long been known to British geologists, respecting the volcanic character of the region specified," with some other remarks based on this strange statement, which has actually no foundation in fact, other than the junction, at those places, of the Laurentian and Lower Silurian rocks, and the occurrence of thick beds of Post-pliocene clay, resting on inclined rock surfaces, and therefore very liable to slip. Captain Bonnycastle's ideas on the subject, referred to by Mr. Twining, were probably founded merely on the irregular contour of the surface, the occurrence of crystalline Laurentian rocks, and the exaggerated accounts of land-slips in previous earthquakes, contained in the memoirs of the Jesuits.

NOTE.—A slight shock of Earthquake was felt at Hawkesbury on the Ottawa on the 3rd January, Dr. Smallwood States that, thought not appreciable at Montreal, it was indicated by the Seimometers.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

(*From the Canadian Naturalist, Vol. VIII. No.* 6.)

THE EARTHQUAKE OF NOVEMBER 4, 1877.

(Read at the November Meeting of the Natural History Society, by PRINCIPAL DAWSON, LL.D., F.R.S.)

In the *Canadian Naturalist*, Vol. V., first series, will be found notes on the earthquake of October 17, 1860, with a summary of facts relating to the previous shocks recorded in Canada, and some general remarks on their periods, local peculiarities and probable causes. The subject was continued in Vol. 1. of the new series, in connection with the earthquake of April, 1864, and in Vol. V., new series, in connection with that of October 20th, 1870. I may refer to these notices for what is known on Canadian earthquakes up to that time, and we may now continue the narrative in connection with the somewhat wide-spread disturbances of the earth's crust in the present autumn.

On January 4th, 1871, a shock was experienced at Hawkesbury, Ontario, but was not reported from any other place. A more extensive earthquake occurred on May 22nd, 1871. It prevailed from the city of Quebec to the western part of Ontario. The time for Quebec is stated at ten minutes before two a. m., and there was a second shock at twenty minutes past three. The time for Perth, Ontario, is stated at half-past one. It is noteworthy that this earthquake occurred at nearly the same time with that recently experienced. Since 1871 several minor shocks have been noticed from time to time, but did not attract much attention, and I have preserved no details in relation to them.

That of the present month was probably the most considerable since 1871. It occurred at Montreal, at ten minutes before two on the morning of Sunday, November 4th. At Montreal there was only one distinct shock, preceded by the usual rumbling noise, and sufficiently severe to be distinctly felt, and to shake window-sashes and other loose objects, causing them to vibrate for several seconds. In so far as the published reports give information, the shock would seem to have been limited to the area along the river St. Lawrence, extending from near Three Rivers on the east, to Kingston on the west, and in a direction transverse to the St. Lawrence from Ottawa to the southern part of New England. In a paper prepared for the American Journal of

Science, by Professor Rockwood, of Princeton, he defines the area in question as that of "an irregular trapezium whose angles are marked by Pembroke, Ont., Three Rivers, P.Q., Hartford, Conn., and Auburn, N. Y., and which is some 200 miles on its northern and southern sides, about 300 miles on the eastern side, and 175 on the western." So far as can be learned from the reports, the shock seems to have been most severely felt on the north side of the valley of the St. Lawrence and about Lake Champlain, or may be said to have had its centre in the Adirondack and Green Mountain region.

In the notice of Canadian earthquakes in 1860, I mentioned that it had been observed that the greatest and most frequent shocks have occurred a little after the middle and toward the close of each century. We are now approaching the latter period, so that possibly the last shock may be the beginning of a series of similar phenomena. Since, however, there is no known reason for this periodicity, it may be a merely accidental coincidence, or may depend on some cycle of about half a century.

If we add to the table of earthquakes in Eastern America, given in Vol. V. of the *Naturalist*, the more recent earthquakes observed in Canada, the proportion for the several months will stand as follows:—

January, 9 earthquakes; February, 4; March, 5; April, 5; May, 7; June, 3; July, 4; August, 6; September, 4; October, 8; November, 15; December, 8. Total, 78.

Thus of seventy-eight recorded Canadian and New England earthquakes, fifteen, or nearly one-fifth, occured in November; forty, or more than half of the total number, in the third of the year, extending from October to January inclusive. The published catalogues show that similar ratios have been observed elsewhere, at least in the Northern hemisphere.

In some earthquakes a low state of the barometer has been observed, as if a diminution of atmospheric pressure was connected with the movements of the crust producing seismic vibrations. This we can readily understand if a low state of the barometer should prevail over an area of the crust tending to rise, simultaneously with a high pressure over a sinking area. In this case a state of previous tension might terminate in a rent of the crust causing vibration. In the present case no very decided indication of such a cause appears, at least in so far as this part of the St Lawrence valley is concerned. Mr. McLeod informs me that the mean barometer for the week preceding the earthquake was 29.7564, and for the following week 30.0864. The barometer on the Friday before the earthquake at 8 p. m. was 29.115, the lowest observed since March last; but at 1.50 a. m. on Saturday it was about 29.967, which is very near the mean of November 1876, and also a little above the mean barometer of the place for the whole year; and on Sunday afternoon it rose to 30.200. It would thus appear that the earthquake was preceded by a low state of the barometer, and followed by one unusually high for the season, and this rapid fluctuation was accompanied with much atmospheric disturbance in the region of the Lakes and the St. Lawrence Valley. The weather map issued by the War Department at Washington for Sunday morning, November 4th, shows a low barometer in the Gulf of St. Lawrence and a high barometer in the Middle States—the area of the earthquake being about half way between the extremes.

In connection with previous earthquakes it has been observed that the greatest intensity of the shocks appeared near the junction of the Laurentian with the Silurian formations. This would be a natural consequence either of the propagation of vibrations upwards from deep underlying regions through the Laurentian rocks, or from the overlying sedimentary rocks towards these older rocks. In the case of the recent earthquake, this appears to have applied chiefly to the border of the Laurentians extending round by the Ottawa and Kingston to the Adirondacks, as if a wave propagated through the Silurian formations had broken against the southern and eastern sides of the Laurentian region, or a shock originating under the Laurentian of these regions had extended itself from them into the Silurian rocks to the south and east. If the prevailing impression stated in the reports, that the vibrations passed from W. to E. or N.W to S.E., is correct, the latter would be the more probable supposition. It is, however, very difficult to attain to any certainty as to the actual direction of the disturbance, and some observers give it as precisely the opposite of that above stated.

In the present year there have been violent earthquake shocks along the chain of the Andes. The latest of these heard of was that of Lima and Callao on the 9th of October. On the west coast of North America, portions of Oregon and Washington

Territories were shaken on the 12th October. On the 14th November a slight shock was felt at Cornwall, Ontario, and on the 15th November earthquake shocks occurred over a wide area in Kansas, Iowa, Dakota and Nebraska.

While the above was in press the following appeared in the daily newspapers :—

"A despatch from Beachburg says:—Two shocks of earthquake were felt here this morning (Dec. 18), the first being between the hours of one and two, and the last between five and six o'clock, the latter being so severe as to shake houses and arouse the inmates from their slumbers."

Beachburg is on the south side of the Ottawa, about twelve miles north-west of Portage du Fort.

[PROOF.]

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

ON RHIZOCARPS IN THE PALÆOZOIC PERIOD.

By J. W. Dawson, of Montreal.

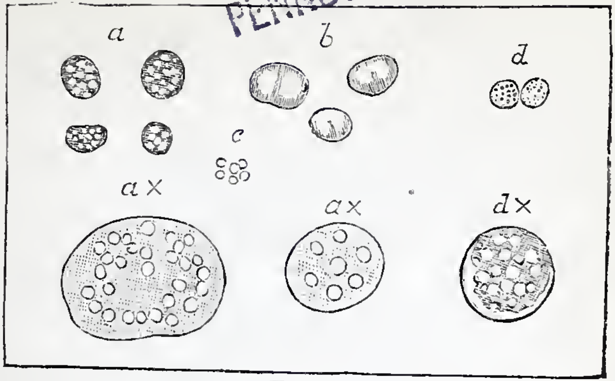

Fig. 1.

(*a*) *Sporangites Braziliensis*, nat. size. (*a*×) same, magnified.
(*b*) *Sp. biloba*, nat. size.
(*c*) Detached macrospores.
(*d*) Spore-cases of *Salvinia natans*. (d×) same magnified.

Some years ago my attention was directed by the late Sir W. E. Logan to a shale from the Erian formation at Kettle Point, Lake Huron, supposed to be on the horizon of the Marcellus shale of New York, and which was filled with minute brownish discs, scarcely more than an hundredth of an inch in diameter, and which I recognized as probably spore-cases or macrospores of some acrogenous plant. They were described in some detail in a paper on "Spore-cases in Coal," published in the *American Journal of Science*, for April, 1871, and reprinted in the *Canadian Naturalist*, new series, Vol. V.

They were described as "flattened disc-like bodies, slightly papillate externally, and with a minute point of attachment at one side and sometimes a slit more or less gaping at the other. Viewed under the microscope as transparent objects, they appear yellow like amber, and show little structure except that the walls can be distinguished from the internal cavity, and the latter is seen in places to contain patches of granular or flocculent matter." They occur in a brown bituminous shale, which burns with much flame. This bed is stated in the Reports of the Geological Survey of Canada to be twelve to fourteen feet in thickness, but whether the fossils are equally abundant throughout its thickness is uncertain. The shale also contains vast numbers of rounded transparent granules which may be escaped spores or microspores.

The only other fossils found in this bed are stems of a species of *Calamites* (*C. inornatus*). and a *Lepidodendron* obscurely preserved, but not improbably the *S. primaevum* of Rogers. My impression at the time when these spore-cases were first examined was that they might have been produced by a *Lepidodendron* or other lycopodiaceous plant.

In July, 1882, my attention was again directed to the subject by Prof. Orton, of Columbus, Ohio, who mentioned to me the occurrence of similar bodies in vast numbers in the Erian and Lower Carboniferous shales of Ohio, known as the Huron, Cleveland and Berea shales. Prof. Orton regarded these bodies as spore-cases, and was disposed to consider them as a main source of the bituminous matter so abundant in these formations in Ohio. He subsequently detailed his observations at the meeting of the American Association at Montreal, and referred to certain thread-like branching stems found with these bodies as possibly connected with them. Though this observation did not seem to be absolutely certain, yet in connection with the very wide distribution of the organisms in marine beds, it served to shake the belief which I had formerly entertained as to the lycopodiaceous affinities of the *Sporangites Huronensis*, which on comparison I found some of Prof. Orton's specimens precisely resembled.

For the geological facts relating to the mode of occurrence of the Ohio specimens, I may refer to Prof. Orton's paper, which appears in the proceedings of the American Association; merely stating that he describes the *Sporangites* as occurring throughout the thickness of the Ohio black shale, amounting to 250 to 300 feet, and which extends over a very wide area in Ohio and the neighbouring States.

At the meeting of the American Association, in the discussion of Prof. Orton's paper, Prof. Williams, of Cornell University, mentioned that he had found similar bodies in the Hamilton shales of New York, and that they were associated with the curious pinnately leaved plant *Ptilophyton Vanuxemii*, an observation to which I subsequently referred in discussing the affinities of this plant, in a report on the Erian plants of Canada, published in 1882.* Prof. Williams was kind enough to send me specimens, in which, however, the round spore-case-like bodies were much less distinct than in the specimens from Ohio and

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* Report on Erian Plants of Canada. Part II.

Lake Huron. In the report above referred to I have also noticed the occurrence of rounded spore-like bodies in association with the stems of *Trochophyllum* of Lesquereux from the lower carboniferous of Pennsylvania, and of which specimens were submitted to me by Mr. Lacoe of Pittston, and Prof. Lesquereux. *Trochopyllum* I regard as closely allied to or perhaps congeneric with *Ptilophyton*, and in the report already referred to have argued that these plants were probably aquatic.

Still more recently Prof. J. M. Clarke, of Northampton, Massachussets, was so kind as send me two fragments of rock containing *Sporangites* similar to those above mentioned—one from the Genessee shale of Canandaigua, N. Y.. and another from the Corniferous Limestone. In the latter these bodies retain their globular form, though some are partially crushed in such a way as to show their membranous character. In slices prepared by Prof. Clarke the wall is seen to be thin and carbonaceous with indications of a dense cellular structure, and some of the specimens show a projecting aperture or point of attachment at one side, giving them a somewhat pear-shaped appearance. The size of all these macrospores from the Erian of New York is nearly the same with that of Lake Huron specimens. Those found with *Trochophyllum* in the Lower Carboniferous are much larger.

No certain clue seemed to be afforded by all these observations as to the precise affinities of these widely distributed bodies; but in March last Mr. Orville Derby, of the Geological Survey of Brazil sent me specimens found along with fronds of *Spirophyton* in the Erian of that country. which seemed to throw a new light on the whole subject. Mr. Derby's specimens recalled to remembrance certain fossils which had been sent to me several years ago by the late Prof. Hartt, and which, like Mr. Derby's specimens, occurred in beds holding *Spirophyton*, though these were at that time regarded as Carboniferous. In a note prepared for Prof. Hartt, but not, so far as I am aware, published, I had noticed these fossils as follows:—

"*Sporangites*—Specimens from a shale at Rio Tapagos, above Haituba.

"These are spore-cases, probably of a Lepidodendroid plant, and appear to be similar to those described by Carruthers (London Geological Magazine), as found in cones from Brazil, referred by him to his genus *Flemingites*.* Carruthers' specimens were from Rio Grande du Sul, and were found in shales associated with beds of coal, and believed to be of Carboniferous age, though the fossil leaves found with them and attributed to *Noeggerathia* and *Odontopteris* would, if interpreted by North American analogies, he supposed to be older than the true coal formation. The present specimens are labelled as Carboniferous, but the occurrence in them of abundant fronds of *Spirophyton* rather points to a Devonian date."

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* Geological Magazine. Vol. VI, p. 151.

Mr. Derby's specimens contain *Spirophyton* and also minute rounded *Sporangites* like those obtained by Prof. Hartt. But they differ in showing the remarkable fact that these rounded bodies are enclosed in considerable numbers in spherical and oval sacs, the walls of which are composed of a tissue of hexagonal cells, and which resemble in every respect the involucres or spore-sacs of the little group of modern acrogens, known as Rhizocarps, and living in shallow water. More especially they resemble the sporocarps of the genus *Salvinia*. This fact opens up an entirely new field of investigation, and I would now proceed to describe these interesting specimens, to inquire as to their probable affinities with modern plants and their probable relations to other palaeozoic forms of vegetation found with them.

Mr. Derby's specimens are labelled as from Rio Trombetos and Rio Curuá. They occur in two kinds of matrix. One is a thinly laminated sandy shale, tinged red with peroxide of iron, and with occasional ferruginous laminae. In this the spore-sacs are flattened and black, and show the structure of the walls under the microscope. The contained macrospores, when visible, appear as minute tubercles or sometimes as depressions on the wall of the envelope or more frequently as round light coloured spots, according to their state of preservation (fig. 1 *a*). The other kind of matrix is a gray dense shale in which the spore-sacs appear less flattened and destitute of carbonaceous matter.

The very numerous spore-sacs contained in these shales are extremely variable in size and form, and may have belonged to several species of plants. They resolve themselves, however, into two leading types, which may be provisionally named *Sporangites Braziliensis* and *S. biloba;* though I would suggest for them, in prospect of the discovery of their vegetative parts, the name *Protosalvinia*. They may be described as follows:—

Sporangites (*Protosalvinia*) *Braziliensis*, S. N. (fig. 1 *a*), Sporocarps thin, carbonaceous, having a structure of dense hexagonal cells and enclosing macro-spores which vary in number from three or four to as many as twenty-five. Form circular, oval or reniform. Longest diameter from three millimetres to six millimetres. Some of the sacs which do not show included round bodies may have held microspores.

S. (*P.*) *biloba*, S.N. (fig. 1 *b*) Sporocarps oval or reniform, three millimetres to six millimetres in diameter, each showing two rounded prominences at the ends, with a depression in the middle, and sometimes a raised neck or isthmus at one side connecting the prominences. Some of the specimens indicate that each prominence or tubercle contained several macrospores. At first sight it would be easy to mistake these bodies for valves of *Beyrichia*.

The geological relations of the beds containing these interesting remains are thus stated by Mr. Derby.*

"The third or Curuá group consists almost exclusively of black and red shales, passing at times into shaly sandstone. These beds form low cliffs along the rivers Maecurú and Curuá for a considerable distance, lying almost horizontal, except where disturbed by eruptions of diorite. On the Trombetas the black shale forms two short cliffs on the river bank and the red shale is badly exposed on a lake near by. At Ereré these rocks are exposed in the eastern part of the plain, and in the base of the serras, particularly that of Tajuri, the front of which is composed entirely of these shales. The black shale forms the lowest bed, the thickness of which, on the Curuá, is estimated by Mr. Smith at 300 feet. It is well laminated, almost slaty in structure, and in the lower part contains numerous large, calcareous and arenaceous concretions. The first are bluish black in colour, have well developed cone-in-cone structure and emit, when struck with a hammer, a strong odour of petroleum."

"The reddish shale lies above the black, having more or less the same thickness. It is generally chocolate-coloured, mottled with spots of a darker hue and banded, parallel with the stratification, with white, yellow or black. The rock consists of clay, mixed with a considerable proportion of finely-divided mica and sand, the last often forming independent layers a few inches thick. The only fossils found in these shales were Fucoids, of the genus *Spirophyton*, and small fruit-like bodies, resembling very much a flattened currant, consisting apparantly of a thin pellicle enclosing two to six small grains. The *Spirophyton* is apparently identical with one of those described by Prof. Hall, from the Hamilton group of New York. It occurs abundantly in all the localities, in both the black and red shale, near the junction of the two."

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* Proceedings of the American Philosophical Society, Feb. 21, 1879.

"On the Curuá and Maecurú the red shale, which is undoubtedly Devonian, is followed by beds of coarse sandstone which, according to Mr. Smith, are at least fifty feet thick on the Curuâ. This is followed by fossiliferous Carboniferous beds. The red shale is also overlaid by coarse sandstone, in the mountains of Ereré, but it is not certain that this sandstone is of the same formation as that of the Curuâ."

"As regards the extension of the Devonian series, it has been recognized as far west as the river Uatumâ, a small river between the Tombetas and the Rio Negro. On the southern side of the valley, there are, on the Tapajos, shales containing *Spirophyton* and calcareous concretions, which were referred provisionally to the Carboniferous by Prof. Hartt, but which seem to me to be Devonian, and I refer to the same age the black shale found by Sñr Penna on the Xingû."

I have not seen specimens of the black shales referred to in this description, but should think it likely that on careful examination they might be found to owe their carbonaceous or bituminous matter to the partial decay of *Sporangites.* They also deserve careful examination with the view to the discovery of the vegetation appertaining to the sporocarps. The similarity of these Brazilian beds to those holding similar fossils in Ohio and Ontario is very striking.

There can be no question of the close resemblance of the Brazilian species of *Sporangites* with the spore-envelopes of modern Rhizocarps. Some individuals of the *S. Braziliensis* are scarcely distinguishable in form or contained macrospores from the sporocarps of *Salvinia natans* of the rivers of Europe (fig. 1 *d*). It is true that the analagy of *Salvinia* would lead us to expect other sacs containing microspores; but in ordinary circumstances the latter could not be preserved in a visible state, and on the Brazilian shales there are many specimens not showing macrospores, and which might have been filled with macrospores which have been flattened into an undistinguishable mass.

If we compare the separate macrospores of the Brazilian sporocarps, and especially those which are found detached from their envelopes, with *Sporangites Huronensis,* we see a remarkable similarity in size, form and texture, sufficient to justify us in supposing that the latter may be of the same nature with the former, but deprived of their outer cases either by dehiscence or by decay, and this is the view which I am now disposed to take of their nature, and which better accords with their wide distribution in aqueous deposits and with their accompaniments than any other supposition. I may add that Prof. Orton and Prof. Clarke, in letters to the author, refer to grouping of the little rounded bodies and traces of enveloping membrane. In this connection I would also mention the sacs containing rounded bodies known as *Parka*, and which have been met with in the Erian beds both in Scotland and in Gaspé, and have been supposed to be ova of crustaceans. It is true that these are much larger than the sporocarps above referred to, but on examination of Gaspé specimens in my collection, I am disposed to suspect that they also may prove to be the fructification of Rhizocarps.

It remains to enquire, Are there any Erian plants known to us in their stems and foliage, to which such organs of fructification as those above described might have belonged ?

A preliminary question would naturally be as to the vegetative organs of modern Rhizocarps. On reference to the descriptions, and to a somewhat extensive collection of specimens placed at my disposal by Mr. Poe Watt, of Montreal, I find that these may be referred to three leading types. Some, like *Pilularia*, have simple linear leaves; others, like *Marsilea*, have leaves in verticils and cuneate in form; while others, like *Azolla* and *Salvinia*, have frondose leaves, more or less pinnate in their arrangement. The first type presents little that is characteristic, but there are in the Erian sandstones and shales great quantities of filamentous and linear objects which it has been impossible to refer to any genus, and which might have belonged to plants of the type of *Pilularia*. It is quite possible also that such plants as *Psilophyton glabrum* and *Cordaites angustifolia*, of which the fructification is quite unknown, may have been allied to Rhizocarps. With regard to the verticillate type, we are at once reminded of *Sphenophyllum*, which many palaeo-botanists have referred to the *Marsiliaceæ*, though like other Palæozoic Acrogens it presents complexities not seen in its modern representatives. *S. primaevum* of Lesquereux is found in the Hudson River group, and my *S. antiquum* in the middle Erian. Besides these there are in the Silurian and Erian beds, plants with verticillate leaves which have been placed with the *Annu-*

lariæ, but which may have differed from them in fructification. *Annularia laxa* of the Erian and *Protannularia Harknessii* of the Silurian may be given as examples. As to pinnate leaves, I have already referred to the remarkable plants of the genus *Psilophyton*, found both in the Erian and Carboniferous, and which seem to have been aquatic in their habit like Rhizocarps. It is deserving of notice also that the two best known species of *Psilophyton* (*P. princeps* and *P. robustius*), while allied to Lycopods by the structure of the stem and such rudimentary foliage as they possess, are also allied, by the form of their fructification, to the Rhizocarps, and not to ferns as some palaeo-botanists have incorrectly supposed.*

I do not suppose that the facts above stated furnish any positive proof that the abundant *Sporangites* of the Erian period were the fructification of Rhizocarps, but they establish a certain probability of this, and invite to farther researches. If it should prove that these humble plants, now so insignificant, culminated in the Palæozoic age, and occupied the extensive submerged flats of that period with an abundant vegetation, producing a great quantity of the bituminous matter found in the resulting beds, this early culmination of the Rhizocarps would be strictly in accordance with other facts in the development of the vegetable kingdom. We may even be permitted to speculate on the existence in the early Palæozoic and Eozoic ages of a rich Rhizocarpean vegetation, anticipating the great development of the Acrogens in the later Palæozoic.

I have not referred above to the well known fact that in certain beds of coal and shale of the Carboniferous period there are multitudes of globular spore-cases or macrospores not dissimilar from those above described. These may have been derived from plants of higher organization than the Rhizocarps, yet it is quite possible that this group of plants may have contributed to them. It is, however, only in the Erian that these *Sporangites* are so widely and abundantly distributed in aquatic beds, and that we have direct evidence as to their origin.

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* See Report on Erian Plants of Canada, 1882.

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February, 1878.

(From the Canadian Naturalist, Vol. VIII. No. 7.)

NOTES
ON SOME
SCOTTISH DEVONIAN PLANTS.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

By J. W. Dawson, LL.D., F.R.S., Principal and Vice-Chancellor
of McGill University, Montreal.

(Read before the Edinburgh Geological Society, 20th Dec. 1877.
D. Milne Home, Esq., LL.D., President, in the chair.)

Since the publication of my Memoirs on Devonian Plants, in the Journal of the Geological Society of London and in the Reports of the Canadian Geological Survey, I have watched with some interest the progress of discovery in the Devonian Flora of Scotland, and desire now to make a few remarks on new and critical forms, and on opinions which have been expressed by workers in this field.

Previously to the appearance of my descriptions of Devonian plants from North America, Hugh Miller had described forms from the Devonian of Scotland, similar to those for which I proposed the generic name *Psilophyton* ; and I referred to these in this connection in my earliest description of that genus.* He had also recognized what seemed to be plants allied to Lycopods and Conifers. Mr. Peach and Mr. Duncan had made additional discoveries of this kind, and Sir J. Hooker and Mr. Salter had described some of these remains. More recently Messrs. Peach, Carruthers and McNab have worked in this field, and in the present year † Messrs. Jack and Etheridge have summed up the facts and have added some that are new.

The first point to which I shall refer, and which will lead to the other matters to be discussed, is the relation of the characteristic *Lepidodendron* of the Devonian of Eastern America, *L. Gaspianum,* to *L. nothum* of Unger and of Salter. At the time when I described this species I had not access to Scottish specimens of *Lepidodendron* from the Devonian, but these had been well figured and described by Salter, and had been identified with *L. nothum* of Unger, a species evidently distinct from mine, as was also that figured and described by Salter, whether identical or not with Unger's species. In 1870 I had for the first time an opportunity to study Scottish specimens in the collection of Mr. Peach; and on the evidence thus afforded I stated confidently that these specimens represented a species distinct from *L. Gaspianum*, perhaps even generically so.[*] It differs from *L. Gaspianum* in its habit of growth by developing small lateral branches instead of bifurcating, and in its foliage by the absence or obsolete character of the leaf-bases and the closely placed and somewhat appressed leaves. If an appearance of swelling at the end of a lateral branch in one specimen indicates a strobile of fructification, then its fruit was not dissimilar from that of the Canadian species in its position and general form, though it may have differed in details. On these grounds I declined to identify the Scottish species with *L. Gaspianum*. The Lepidodendron from the Devonian of Belgium described and figured by Crepin,[†] has a better claim to such identification, and would seem to prove that this species existed in Europe as well as in America. I also saw in Mr. Peach's collection in 1870, some fragments which seemed to me distinct from Salter's species, and possibly belonging to *L. Gaspianum*.[‡]

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* Journal Geological Society, London, 1859.

† Ibid, 1877.

In the earliest description of *Psilophyton* I recognized its probable generic affinity with Miller's 'dichotomous plants,' with Salter's 'rootlets,' and with Goeppert's *Haliserites Dechenianus*, and stated that I had "little doubt that materials exist in the Old Red Sandstone of Scotland for the reconstruction of at least one species of this genus." Since, however, Miller's plants had been referred to coniferous roots, and to fucoids, and Goeppert's *Haliserites* was a name applicable only to fucoids, and since the structure and fruit of my plants placed them near to Lycopods, I was under the necessity of giving them a special generic name, nor could I with certainty affirm their specific identity with any European species. The comparison of the Scottish specimens with woody rootlets, though incorrect, is in one respect creditable the acumen of Salter, as in almost any state of preservation xperienced eye can readily perceive that branchlets of

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t on Devonian Plants of Canada, 1871.

ions sur quelques Plantes Fossiles des dépôts Devoniens.

s Geological Society of London, March 1871.

Psilophyton must have been woody rather than herbaceous, and their appearance is quite different from that of any true Algae.

The type of *Psilophyton* is my *P. princeps*, of which the whole of the parts and structures are well known, the entire plant being furnished in abundance and in situ in the rich plant-beds of Gaspé. A second species, *P. robustius*, has also afforded well characterized fructification. *P. elegans*, whose fruit appears as "oval scales," no doubt bore sac-like spore-cases resembling those of the other species, but in a different position, and perfectly flattened in the specimens procured. The only other Canadian species, *P. glabrum*, being somewhat different in appearance from the others, and not having afforded any fructification, must be regarded as uncertain.

The generic characters of the three first species may be stated as follows :—

Stems dichotomous, with rudimentary subulate leaves, sometimes obsolete in terminal branchlets and fertile branches ; and in decorticated specimens represented only by punctiform scars. Young branches circinate. Rhizomata cylindrical, with circular root-areoles. Internal structure of stem, an axis of scalariform vessels enclosed in a sheath of imperfect woody tissue and covered with a cellular bark more dense externally. Fruit, naked sac-like spore-cases, in pairs or clusters, terminal or lateral.

The Scottish specimens conform to these characters in so far as they are known, but not having as yet afforded fruit or internal structure, they cannot be specifically determined with certainty. More complete specimens should be carefully searched for, and will no doubt be found.

In Belgium, M. Crepin has described a new species from the Upper Devonian of Condroz under the name *P. Condrusianum*, [1875]. It wants however some of the more important characters of the genus, and differs in having a pinnate ramification giving it the aspect of a fern. In a later paper [1876] the author considers this species distinct from *Psilophyton*, and proposes for it a new generic name *Rhacophyton*. In a note he states that Mr. Carruthers informs him that he regards *Psilophyton* as founded on the axes of *Lepidodendra* and on the fruit of ferns of the genus *Rhodea* of Stur. For this statement I have no published authority on the part of the English botanist, and it is certainly quite destitute of foundation in nature. My original specimens of *Psilophyton* are low plants with slender stems growing from *rhizomata*, and their leaves and fruits are attached to them, while *Rhodea* is merely a provisional genus formed to include certain ferns of the Hymonophyllid group, but otherwise of uncertain affinities. In the same note M. Crepin intimates that Mr. Carruthers has abandoned his *Psilophyton Dechenianum*, published in the Journal of Botany for 1843, and in which he had included Salter's *Lepidodendron nothum* and *Lycopodites Milleri* and "rootlets," as well as Goeppert's *Haliserites Dechenianus* and a peculiar plant given to him by Sir P. Egerton! * Such a change of opinion I must admit to be judicious. The fact that these plants could, even conjecturally, be identified by a skilful botanist, shows however how imperfectly they are known, and warrants some investigation of the causes of this obscurity, and of the true nature of the plants.

The characters given by Mr. Carruthers in his paper of 1873 for the species *P. Dechenianum*, are very few and general:—"Lower branches short and frequently branching, giving the plant an oblong circumscription." Yet even these characters do not apply, so far as known, to Miller's fucoids or Salter's rootlets or Goeppert's *Haliserites*. They merely express the peculiar mode of branching already referred to in Salter's *Lepidodendron nothum*. The identification of the former plants with the *Lepidodendron* and *Lycopodites* indeed rests only on mere juxtaposition of fragments, and on the slight resemblance of the decorticated ends of the branches of the latter plants to *Psilophyton*. It is contradicted by the obtuse ends of the branches of the *Lepidodendron* and *Lycopodites*, and by the apparently strobilaceous termination of some of them.

Salter's description of his *Lepidodendron* is quite definite, and accords with specimens placed in my hands by Mr. Peach:—"Stems half an inch broad, tapering little, branches short; set on at an acute angle, blunt at their terminations. Leaves in seven to ten rows, very short, not a line long and rather spreading than closely imbricate." These characters however, in so far as they go, are rather those of the genus *Lycopodites* than of *Lepidodendron*, from which this plant differs in wanting any distinct leaf-bases, and in its short crowded leaves. It is to be observed that they apply also to Salter's *Lycopodites Milleri*, and that the difference of the foliage of that species may be a result merely of different state of preservation. For these reasons I am disposed to place these two supposed species together, and to retain for the species the name *Lycopodites Milleri*. It may be characterized by the description above given, with merely the modification that the leaves are sometimes one-third of an inch long and secund.

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* Mr. Carruthers has elsewhere identified *Lepidodendron nothum* and *L. Gaspianum* with *Leptophleum rhombicum*, and this with an Australian species collected by Mr. Daintree in Queensland, but which I subsequently found to be a species allied to the well known *Lepidodendron tetragonum* of the Lower Carboniferous, and which had been previously discovered by Mr. Selwyn in the Carboniferous of Victoria. See Carruthers' paper in the Journal of the Geological Society, vol. 28, and my criticism in vol. 29, which last was however only printed in abstract, and with some comments under the head of "Discussion," to which if present I could have very easily replied.

Decorticated branches of the above species may no doubt be mistaken for *Psilophyton*, but are nevertheless quite distinct from it, and the slender branching dichotomous stems, with terminations which, as Miller graphically states, are "like the tendrils of a pea," are too characteristic to be easily mistaken, even when neither fruit nor leaves appear. With reference to fructification, the form of *L. Milleri* renders it certain that it must have borne strobiles at the ends of its branchlets, or some substitute for these, and not naked spore-cases like those of *Psilophyton*.

The remarkable fragment communicated by Sir Philip Egerton to Mr. Carruthers,* belongs to a third group, and has I think been quite misunderstood. I am enabled to make this statement with some confidence, from the fact that the reverse or counterpart of Sir Philip's specimen was in the collection of Sir Wyville Thomson, and was placed by him in my hands in 1870. It was noticed by me in a paper on New Devonian Plants, in the Journal of the Geological Society of London in 1871, in the following terms:—

"In his recently published 'Paléontologie,' Schimper (evidently from inattention to the descriptions and want of access to specimens) doubts the Lycopodiaceous character of species of *Lycopodites* described in my papers in the Journal of this Society from the Devonian of America. Of these *L. Richardsoni* and *L. Matthewi* are undoubtedly very near to the modern genus *Lycopodium*. *L. Vanuxemii* is, I admit, more problematical; but Schimper could scarcely have supposed it to be a fern or a fucoid allied to *Caulerpa* had he noticed that both in my species and the allied *L. pennæformis* of Goeppert, which he does not appear to notice, the pinnules are articulated upon the stem, and leave scars where they have fallen off. When in Belfast last summer I was much interested by finding in Prof. Thomson's collection a specimen from Caithness, which shows a plant apparently of this kind, with the same long narrow pinnae or leaflets, attached, however, to thicker stems, and rolled up in a circinate manner. It seems to be a plant in vernation, and the parts are too much crowded and pressed together to admit of being accurately figured or described; but I think I can scarcely be deceived as to its true nature. The circinate arrangement in this case would favour a relationship to ferns; but some Lycopodiaceous plants also roll themselvea in this way, and so do the branches of the plants of the genus *Psilophyton.*"

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* Journal of Botany, 1873.

No figure of the plant was given, and Mr. Carruthers, if he noticed the reference, very probably did not connect it with the plant which he received from Sir Philip Egerton. His figure however, published in the Journal of Botany for 1873, leaves no room to doubt that he has had in his possession the counterpart of Thomson's specimen, of which a figure is given in this paper. My interpretation of it differs considerably from his, and as the matter is of some palæontological interest, I shall proceed to describe the specimen from my point of view.

The specimen consists of a short erect stem, on which are placed somewhat stout alternate branches, extending obliquely outward and then curving inward in a circinate manner. The lower ones appear to produce on their inner sides short lateral branchlets, and upon these and also upon the curved extremities of the branches, are long narrow linear leaves placed in a crowded manner, and which are the "tufts of linear bodies" referred to by Mr. Carruthers. The specimen is thus not a spike of fructification but a young stem or branch in vernation, and which when unrolled would be of the form of those peculiar pinnate *Lycopodites* of which *L. Vanuxemii* of the American Devonian and *L. pennæformis* of the European Lower Carboniferous are the types, and it shows, what might have been anticipated from other specimens, that they were low tufted plants, circinate in vernation. The short stem of this plant is simply furrowed, and bears no resemblance to the detached branch of *Lycopodites Milleri* which lies at right angles to it on the same slab (see figure). As to the affinities of the singular type of plants to which this specimen belongs, I may quote from my Report on the Lower Carboniferous plants of Canada, in which I have described an allied species, *L. plumula* :—

" The botanical relations of these plants must remain subject to doubt, until either their internal structure or their fructification can be discovered. In the mean time I follow Goeppert in placing them in what we must regard as the provisional genus *Lycopodites.* On the one hand they are not unlike the slender twigs of *Taxodium* and similar Conifers, and the highly carbonaceous character of the stems gives some colour to the supposition that they may have been woody plants. On the other hand, they might, in so far as form is concerned, be placed with algae of the type of Brongniart's *Chondrites obtusus*, or the modern *Caulerpa plumaria.* Again, in a plant of this type from the Devonian of Caithness to which I have referred in a former memoir, the vernation seems to have been circinate, and Schimper has conjectured that these plants may be ferns, which seems also to have been the view of Shumard."

On the whole these plants are allied to Lycopods rather than to Ferns; and as they constitute a small but distinct group, known only in so far as I am aware in the Lower Carboniferous and Erian or Devonian, they deserve a generic name, and I would propose for them that of *Ptilophyton*, a name sufficiently distinct in sound from Psilophyton, and expressing very well their peculiar feather-like habit of growth. This genus may for the present be defined as follows:—

Branching plants, the branches bearing long slender leaves in two or more ranks, giving them a feathered appearance; vernation circinate. Fruit unknown, but analogy would indicate that it was borne on the bases of the leaves or on modified branches with shorter leaves.

I would name the present species *Pt. Thomsoni*, and would characterize it by its densely tufted form and thick branches, until specimens more fully developed shall be found. The other species will be:—

Pt. pennæformis, Goeppert, L. Carboniferous.
Pt. Vanuxemii, Dawson, Devonian.
Pt. plumula, Dawson, L. Carboniferous.

Shumard's *Filicites gracilis*, from the Devonian of Ohio, and Stur's *Pinites antecedens*, from the Lower Carboniferous of Silesia, may possibly belong to the same genus. The present specimen is apparently the first appearance of this form in the Devonian of Europe.

Mr. Salter described in 1857 * fragments of fossil wood from the Scottish Devonian, having the structure of *Dadoxylon*, though very imperfectly preserved; and Prof. McNab has proposed † the generic name *Palæopitys* for another specimen of coniferous wood collected by Hugh Miller, and referred to by him in the "Testimony of the Rocks." From Prof. McNab's description, I should infer that this wood may after all be generically identical with the woods usually referred to *Dadoxylon* of Unger (*Araucarioxylon* of Kraus). The description, however, does not mention the number and disposition of the rows of pores, nor the structure of the medullary rays, and I have not been able to obtain access to the specimens themselves. I have described three species of *Dadoxylon* from the Middle and Upper Erian of America, all quite distinct from the Lower Carboniferous species. There is also one species of an allied genus *Ormoxylon*, besides the somewhat exceptional *Prototaxites*, which occurs in the Lower Erian, not far above the top of the Upper Silurian. All these have been carefully figured, and it is much to be desired that the Scottish specimens should be re-examined and compared with them.

Prof. Alleyne Nicholson has kindly placed in my hands some ancient plants which though not Scottish nor Devonian are of interest in this connection. One of these is a specimen from the Lower Ludlow of Bow Bridge. From its regular ramification, its apparently woody structure, and its traces of rudimentary leaflets, it may not improbably belong to the genus *Psilophyton*. If so, this genus occurs at about as low a horizon in Europe as in Canada.

The remarkable plants from the Skiddaw slates described by Nicholson as *Buthotrephis Harknessi* and *B. radiata* ‡ have also been examined by me, as well as some additional specimens from the same formation collected by Dr. G. M. Dawson. Nicholson says of the latter species:—"If its vegetable nature be conceded, it can hardly be referred to the Algae." It seems not unlikely, as Nicholson indeed suggests, that both plants may belong to the same species, and that this had the habit of growth of *Annularia* and resembled *A. laxa* of the American Devonian.

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* Journal London Geological Society.

† Transactions Edinburgh Botanical Society, 1870.

‡ Geological Magazine, Vol. VI.

If a land plant it is probably the oldest at present certainly known.*

With these plants, Prof. Nicholson sent a fibrous body from the Upper Llandeilo of Hart Fell, near Moffat, which at first sight had the appearance of a fragment of coarse-grained wood. On microscopic examination of it, however, I concluded that it had been a bundle of spicules of a sponge of the type of *Hyalonema.* This I still believe to be its true nature.

In studying the plants of the older rocks, the botanist requires to be on his guard as to the Algæ and Zoophytes of these formations which simulate land plants. In the latter group I know no forms more deceptive than those of Hall's genus *Inocaulis*, which is regarded as a relative of the Graptolites. A specimen now before me, from the collection of Col. Grant, of Hamilton, Ontario, in its ramification and appearance of foliage, bears the closest resemblance to a lycopodiaceous plant, and I have seen what appears to be the base of a *Dictyonema* from the Niagara formation, which might readily be mistaken for a small and peculiar species of *Psilophyton*.

Messrs. Jack and Etheridge have given an excellent summary of our present knowledge of the Devonian Flora of Scotland, in the Journal of the London Geological Society. From this it would appear that species referable to the genera *Calamites*, *Lepidodendron*, *Lycopodites*, *Psilophyton*, *Arthrostigma*, *Archæopteris*, *Caulopteris*, *Palæopitys*, *Araucarioxylon*, and *Stigmaria* have been recognized.

The plants described by those gentlemen from the Old Red Sandstone of Callender, I should suppose, from their figures and descriptions, to belong to the genus *Arthrostigma*, rather than to *Psilophyton.* I do not attach any importance to the suggestions referred to by them, that the apparent leaves may be leaf-bases. Long leaf-bases, like those characteristic of *Lepidofloyos*, do not occur in these humbler plants of the Devonian. The stems with delicate "horizontal processes" to which they refer may belong to *Ptilophyton* or to *Pinnularia*.

In conclusion, I need scarcely say that I do not share in the doubts expressed by some British Palæontologists as to the distinctness of the Devonian and Carboniferous Floras. In Eastern

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* Since the above was written, Lesquereux has described supposed land plants from the Cincinnati Group (Lower Silurian) of Ohio. Saporta has discovered what he regards as a fern in rocks of similar age in France, and Claypole will shortly describe an apparently lepidodendroid tree (*Glyptodendron*) from the Clinton Group of Ohio; but neither of these is quite so old as the Skiddaw plants.

America, where these formations are mutually unconformable, there is, of course, less room for doubt than in Ireland and in Western America, where they are stratigraphically continuous. Still, in passing from the one to the other, the species are for the most part different, and new generic forms are met with, and, as I have elsewhere shown, the physical conditions of the two periods were essentially different.*

It is, however, to be observed that since, as Stur and others have shown, *Calamites radiatus* and other forms distinctively Devonian in America, occur in Europe in the Lower Carboniferous, it is not unlikely that the Devonian Flora, like that of the Tertiary, appeared earlier in America. It is also probable, as I have shown in the Reports already referred to, that it appeared earlier in the Arctic than in the Temperate zone. Hence an Arctic or American Flora, really Devonian, may readily be mistaken for Lower Carboniferous by a botanist basing his calculations on the fossils of temperate Europe. Even in America itself, it would appear from recent discoveries in Virginia and Ohio. that certain Devonian forms lingered longer in those regions than further to the North-east;† and it would not be surprising if similar plants occurred in later beds in Devonshire or in the South of Europe than in Scotland. Still, these facts, properly understood, do not invalidate the evidence of fossil plants as to geological age, though errors arising from the neglect of them are still current.

I trust that Scottish workers in this interesting though difficult branch of investigation, will be encouraged by the success they have already attained to still more diligent search. In collecting, the smallest and most obscure fragments should not be neglected. Such specimens, when placed in due relation to others previously obtained, may reveal the most important truths; or if by themselves unintelligible, may be rendered valuable by subsequent discoveries. The greatest care should be taken to rescue every portion of the specimens found, and to keep together those that belong to the same plant; and every fragment likely to show microscopic structure should be carefully preserved. Painstaking work of this kind will be sure to be rewarded by important discoveries; and I know by long experience that none other is likely to be successful.

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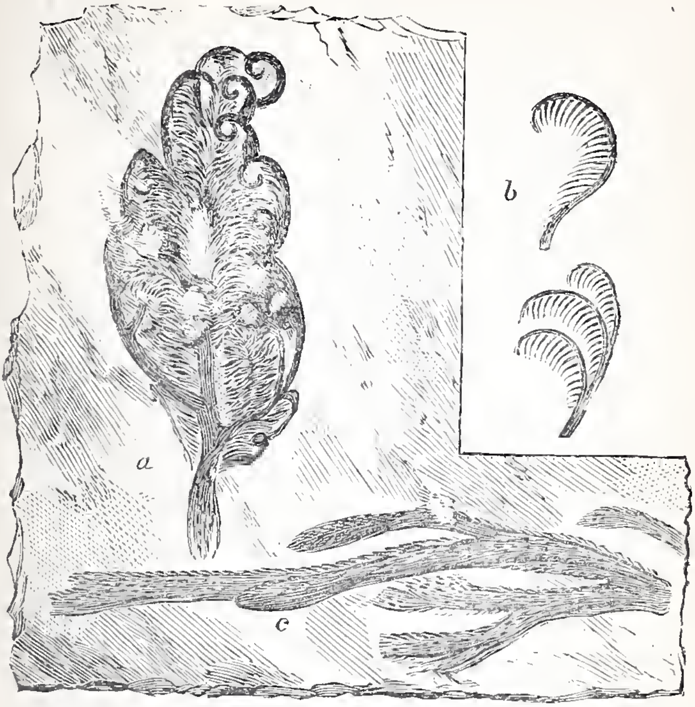
* Reports on Devonian Plants and Lower Carboniferous Plants of Canada.

† Andrews, Palæontology of Ohio, Vol. II. Meek, Fossil Plants from Western Virginia, Philos. Society, Washington, 1875,



PTILOPHYTON THOMSONI.

(*a*) Impression of plant in vernation.

(*b*) Branches conjecturally restored.

(*c*) Branches of *Lycopodites Milleri.*

In this cut the parts of the fossil are given more coarsely and distinctly than in the original.

NEW FACTS RESPECTING THE GEOLOGICAL RELATIONS AND FOSSIL REMAINS OF THE SILURIAN IRON ORES OF PICTOU, NOVA SCOTIA.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA

By J. W. Dawson, LL.D., F.R.S.

(*From the Canadian Naturalist*, Vol. IX. No. 6.)

NEW FACTS RESPECTING THE GEOLOGICAL RELATIONS AND FOSSIL REMAINS OF THE SILURIAN IRON ORES OF PICTOU, NOVA SCOTIA.

By J. W. Dawson, LL.D., F.R.S.

(Read before the Natural History Society of Montreal, April 5th, 1880.)

The subject of this paper has already been discussed by me in various previous publications; and most recently in a paper read at the Portland meeting of the Association for the Advancement of Science in 1874, and published in the Journal of this Society; and in the Supplement to the second edition of "Acadian Geology," 1878. In these publications I have described the general arrangement of the Rocks of the Cobequid Series in the rising grounds on both sides of the East Branch of the East River of Pictou, the superposition on these of Upper Silurian rocks holding bedded red hematite, and the occupation of the valley itself by a narrow band of Lower Carboniferous beds.

I may explain that the name "Cobequid group" was proposed in my Acadian Geology, 1868, for the series of schistose and crystalline rocks constituting the axis of the Cobequid hills, and extending eastward from these, with some partial interruption, through the hilly districts of southern Pictou. In the Cobequid hills, where these rocks are well exposed, they consist of two members: (1) an upper series of gray and dark slates and quartzites with a band of crystalline limestone and veins of iron ores; (2) a lower series consisting largely of felsite, porphyry and agglomerate. Both series are penetrated by dykes and masses of red syenite and dark-coloured diabase, the latter cutting also the overlying Silurian rocks. These last, as seen at Wentworth and New Annan, overlie unconformably the Cobequid group, and afford fossils characteristic elsewhere of the Upper Silurian system. The least antiquity that can be assigned to the Cobequid rocks is thus that of the Siluro-Cambrian; and by some, on the ground chiefly of mineral character, they have been regarded as Huronian. I have ventured to suggest, on the evidence of their relations to the Upper Silurian beds, and to the apparently older Cambrian series of the Atlantic coast, that they may be representatives of the Skiddaw and Borrowdale series of England, and of the Quebec group of the Lower St. Lawrence.

These rocks, in their extension into Pictou County, present characters not dissimilar from those seen in the Cobequids. On the high ground on the west side of the east branch of the East River, they consist of thick beds of gray and dark slate and quartzite, having a general strike of N. 20° to 30° W., and with very high dips to the S.W. They include a great vein of specular iron ore, associated with magnetite, ankerite, and limonite, of the same character with that so well known on the south side of the Cobequids in Londonderry.

The river valley, which not improbably occupies an ancient line of fracture, presents a narrow trough of Lower Carboniferous rocks, containing limestone and gypsum; and at the junction of these Carboniferous beds with the older rocks, on the east side of the river, there is a fissure vein, filled with Limonite, and in some places attaining to large dimensions.

The hills on the east side of the river consist largely of hard gray slates, nacreous slates, obscure diorites, agglomerate and felsite, with syenitic dykes and masses. They correspond very nearly in mineral character with the Lower Cobequid series, and though rudely parallel to the slates on the opposite side of the river, they have so suffered from fractures and unequal denudation that they present a very irregular surface, in the depressions of which are the Upper Silurian hematites and their associated beds; and these rocks also succeed those of the Cobequid series to the north-eastward, forming a long line of outcrop extending from the East River of Pictou towards Arisaig. Thus the general geological character of the region is similar to that of the Cobequid hills, though locally more irregular and with larger areas of Upper Silurian beds.

So far the structure of the district has been pretty well known for some time, but its somewhat complex details have been little worked out, except in connection with the tracing of the iron deposits, in which some explorations have been made, more especially by Dr. G. M. Dawson, Mr. Gilpin, and the writer. For several years the principal iron properties have been under the care of E. Gilpin, Esq., F.G.S., now Superintendent of Mines for Nova Scotia, and his surveys have thrown much light on the distribution of the strata containing the bedded iron ores, indicating approximately the dimensions and direction of the troughs resting on the Cobequid series, and the distribution of those which flank that series on the north-east. More especially these researches have shewn that there are two distinct beds of iron ore, separated by a considerable thickness of slaty and quartzose strata,* and underlaid by slate, sandstone, and conglomerate or breccia, differing from those of the Cobequid series. I do not propose here to enter into the details of these observations, but merely to notice their relations to the palæontology of the district.

The fossils collected in the district were obviously referable to the "Arisaig series," ranging from the Clinton to the Lower Helderberg inclusive, but the new facts indicated in Mr. Gilpin's manuscript map, which he has kindly communicated to me, suggested more careful local comparisons; and as my collections, though extensive, had not been made with reference to the new details of distribution, I thought it desirable to supplement them with additional material. This was obtained by Mr. Donald Fraser of Springville, a well known explorer of these rocks, who by my request visited all the exposures of the iron ores, and collected the fossils found in the ore itself and the including beds, keeping the specimens from each locality separate. In this way a large number of additional specimens were obtained, forming a series of local collections representing the different ore horizons.

The general result of the study of these specimens is to show that both beds of iron ore are Upper Silurian, and approximately of Lower Helderberg age. As compared with the typical Arisaig series, as defined in Acadian geology, they represent the middle and upper part of that series.

The fossils referred to are unfortunately not always in the best state of preservation. They are contained in hard rock, from which they are extracted with difficulty, and are often best studied in the impressions left when they are weathered out. They are also not infrequently distorted. For these reasons it is not always possible to be certain as to their identification; and in cases of doubt I have given a reference to the known species which they most nearly resemble.

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* In a work on the "Mines and Mineral Lands of Nova Scotia," received while this paper was in the press, Mr. Gilpin estimates the thickness of intervening beds at 700 feet.

In the lower bed of iron ore, as represented at the Webster and Blanchard locations, the following fossils have been recognized; though in these beds the fossils are neither so abundant nor so well preserved as in the upper beds. Those marked with an asterisk are found also at Arisaig.

* *Stenopora* (*Chaetetes*) (allied to *S. fibrosa*).
* *Crinoid* stems.
* *Chonetes Novascotica*, Hall.
* *C. tenuistriata*, Hall.
* *Spirifer rugae-costa*, Hall.
S. —— (a large species allied to *S. arenosa.*)
* *Strophomena profunda*, Hall.
* *S. rhomboidalis*, Wilck.
* *Rhynchonella Saffordi*, Hall.
R. —— (large species with about 20 prominent undivided ribs, very characteristic of some parts of the iron ore.)
R. allied to *R. nobilis*, Hall.
Pentamerus (allied to *P. pseudo-galeatus*).
Stricklandinia Billingsi, n. s. (see infra).
Rensselæria æquiradiata, Conrad.
* *Orthis testudinaria*, Dalman.
Platyceras, sp.
Platyostoma depressa, Hall, or allied.
* *Orthoceras*, annulated (allied to *O. ibex*).
* *O. punctostriatum*, Dawson.
* *Cornulites flexuosus*, Hall.
* *Calymene Blumenbachii*, Brong.
* *Homalonotus Dawsoni*, Hall.
Homalonotus (finely banded pygidium ? n. s.)

These fossils are not numerous, but they present the same partly Clinton and partly Upper Helderberg facies seen in the middle portion of the Arisaig series.

At the Ross location, East River, at the Holmes location, west side of Sutherland's River, and at the east side of Sutherland's River, in outcrops believed to be those of the upper bed, the following species occur:—

* *Stenopora* (allied to *S. fibrosa*).
Syringopora, sp.
Cladopora (slenderly branching species).
* *Crania Acadiensis*, Hall.

* *Spirifer subsulcatus*, Hall.
* *Sp. rugae-costa*, Hall.
Sp. (large species similar to that in last list.)
* *Chonetes Nova Scotica*, Hall.
* *Strophomena rhomboidalis*, Wilck.
* *S. Gilpini*, n. s. (see infra).
* *Orthis testudinaria*, Dalman.
O. perelegans, Hall (or allied).
O. discus, Hall (or allied).
Strophodonta varistriata, Hall (or allied).
* *Rhynchonella Saffordi*, Hall.
R. vellicata, Hall (or allied).
R. pyramidata, Hall (or allied).
* *Atrypa reticularis*, Linn. (coarsely ribbed variety).
Stricklandinia Billingsi, n. s. (see infra).
Pentamerus sp.
Discina (smooth conical species like *D. oblongata*, Portlock (see infra).
* *Cytherodon sulcatus*, Billings.
* *Megambonia cancellata*, Hall (see infra).
* *M. striata*, Hall.
* *Pteronitella curta*, Billings.
* *P. oblonga*, Billings.
* *P. venusta*, Billings (or allied).
Avicula textilis, Hall (or allied).
A., new species ? (see infra).
* *Clidophorus concentricus*, Hall.
* *C. elongatus ?* Hall.
* *Grammysia remota*, Billings.
* *Murchisonia Arisaigensis*, Hall.
* *M. acicula*, Hall.
Platyostoma depressa, Hall (or allied).
Cyrtoceras subrectum, Hall.
Cyrtoceras, n. s. (see infra).
* *Orthoceras punctostriatum*, Dawson.
* *Cornulites flexuosus*, Hall.
C. n. s. (see infra).
* *Homalonotus Dawsoni.*
H. (smooth pygidium, allied to *H. delphinocephalus*).
* *Calymene Blumenbachii* (large and small varieties or sub-species).

Phacops caudatus (or allied).
Dalmania, allied to *D. micrurus*, Hall.
* *D. Logani*, Hall.

It will be seen that, while the majority of the species found in the lower bed occur also in the upper, the latter is much richer in species, and especially in those of the Upper Arisaig or Lower Helderberg proper. It is also remarkable for its much greater number of Lamellibranchiate shells and Trilobites. On the other hand it presents no points of resemblance with the Oriskany fossils which accompany the ore of Nictaux in the western part of Nova Scotia.*

The fossils above referred to are derived from the beds immediately containing the iron ore deposits, or from the ore-beds themselves. But in many parts of the district there are rich fossiliferous beds, the relation of which to the iron ores is not so manifest, though they obviously belong to the same great series of deposits. From these beds I have obtained specimens of nearly all the species above catalogued, and some others in addition. The most important of these latter are the following:

Zaphrentis, sp. not determinable.
Meristella didyma, Dalman. A well-known European Upper Silurian species, plentiful in some beds on the East River, but which I have not yet seen from Arisaig.
Lingula sp.
Rhynchonella transversa, Hall (or allied).
R. allied to *R. acutiplicata*, Hall.
R. equiradiata, Hall (or allied).
Orthis multistriata, Hall (or allied).
* *Atrypa emacerata*, Hall.
* *Trematospira Acadiœ*, Hall.
* *Goniophora consimilis*, Billings.
* *Grammysia Acadica*, Billings.
* *Clidophorus concentricus*, Hall.
* *C. cuneatus*, Hall.
* *Modiolopsis rhomboidea*, Hall.
* *M. sub-nasutus*, Hall.
* *Bucania trilobita*, Hall.
Bellerophon, allied to *B. carinatus*, Sowerby.

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* See paper in this Journal, 1879, on 'Recent Papers on the Geology of Nova Scotia.'

Platyceras, allied to *P. pyramidatum*, Hall.
* *Orthoceras exornatum*, Dawson.
O. Pictoense, n. s. (see infra).
O. elegantulum, Dawson.
* *Beyrichia pustulosa*, Hall.
Acidaspis, a small species allied to *A. tuberculata* of Hall (see infra.)
Illænus.—pygidium.

In the second edition of Acadian Geology, 1868, the author published a list of fossils, including many of the more characteristic species above-named, and summed up his conclusion as to their age, as follows: "On the whole I regard the beds seen on the East River of Pictou as belonging to the same line of outcrop with the Arisaig series; but as probably containing in addition to the Upper member of that series beds somewhat higher in position." The fossils more recently collected so far modify this conclusion that I cannot affirm the existence of beds upward as far as the Oriskany, but must be content to regard the highest fossiliferous beds of the East River Silurian as about the horizon of the highest of those seen at Arisaig.

It still remains to inquire as to beds older than the Upper and Middle Arisaig series. As to these great caution is necessary, owing to the paucity of fossils, and to the liability to confound the Upper Silurian rocks with those of the Cobequid group.

Coming up in the anticlinals, and along the flanks of the masses of older rock, there are beds of conglomerate, brown and white quartzite and hard slates, which seem to underlie the fossiliferous beds holding the iron ores, and may represent lower members of the Upper Silurian series. In these beds vermicular markings, perhaps fucoidal and perhaps burrows of annelids, occur near Cameron's brook, and in the same beds are fragments of *Lingulæ*. I have little doubt that these beds are lower than those holding the iron ores, though probably not below the base of the Upper Silurian. On McLellan's Brook, Mr. Fraser has found beds holding casts of *Zaphrentis*, which may not improbably be older than the Lower Helderberg. The tail of *Illænus* referred to above was found in a small ore-bed on the Fraser (Saddler) location, and which I believe to be not improbably lower than the great beds of Hematite. These are the only fossils known to me at present, which indicate a horizon older than the Middle Arisaig. There are, however, great masses of older rock which have afforded no fossils, and which probably underlie those just referred to and may be Lower Silurian beds tending downward to the Cobequid series and connected with it.

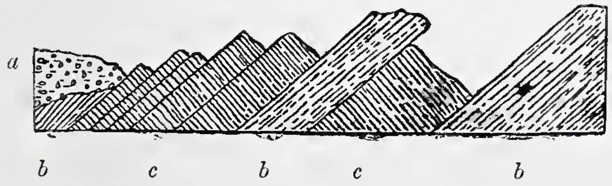
Rocks of this character are well developed in the basin of Lake Murdoch, where, according to Mr. Gilpin, they are cut off from the Blanchard ore-series by a fault on the southern side. They are traceable to the eastward, apparently underlying the beds associated with the "Webster" ore-bed, and are well seen still further to the eastward on the upper waters of the French River. These beds differ considerably in mineral character from any others in the district, though resembling in this respect rocks seen at the Blue Mountain, near Eden Lake, and on the East Branch of the St. Mary's River. They contain thick beds of Nacreous or Hydro-mica slates, coarse slates, sometimes having a conglomerated or brecciated appearance, green chloritic or epidotic rocks, quartzite and agglomerate, and felsitic rocks. They have afforded no fossils, and appear to me to be quite distinct from the Upper Silurian formation. In the meantime they may be connected with the Cobequid series, with the typical rocks of which series they are certainly closely associated farther to the eastward.

One of the marked features of the Upper Silurian in the district in question is the great development of bedded red hematite, and of rocks more or less impregnated with this ore. With reference to its origin, this ore is evidently a marine deposit, and formed under conditions sufficiently favorable to marine life to enable it to contain many shells of Brachiopods and remains of other animals. It is evidently a chemical deposit or precipitate, and often assumes an oolitic structure. In the coarser or more impure beds the little concretions of oxide of iron often surround grains of sand, and the ore passes into a ferruginous sandstone. The following section taken from a MS. Report of Dr. G. M. Dawson shows the great development of the lower bed in one of its exposures. These deposits of iron ore apparently began locally in an early part of the Upper Silurian period, and were continued into the Lower Helderberg period, while in the western part of Nova Scotia, in the Nictaux district, we have evidence of their continuance into the Oriskany age.

Another marked feature of these deposits is the absence of any representative of the great Niagara limestone, and the consequent passage upward of Clinton deposits into those of Lower Helderberg age. This absence of the Niagara limestone is general in Nova Scotia, and along the Atlantic margin of North America. Farther West, in Northern New Brunswick, and in Gaspe, massive limestones appear, but they attain their greatest development in the interior plateau south of the great lakes.

With reference to the dates and disturbances of these deposits, it may be affirmed that there was much volcanic action at the time of the deposition of the Cobequid series; that this series experienced no little disturbance and alteration before the Upper Silurian rocks were laid down; that the latter were subsequently much folded and fractured before the Carboniferous Period, and that since that period there has been sufficient movement to cause the carboniferous rocks to be locally highly inclined and faulted. In the trappean beds, interstratified with the Lower Carboniferous conglomerates of the coast to the eastward, there is evidence of the continuance of igneous action up to that time. As to the age of the iron deposits, the formation of the great veins of specular iron and ankerite was probably contemporaneous with the earliest disturbances of the Cobequid series, and previous to the Lower Helderberg age. The great interstratified beds of Hematite are undoubtedly of the latter age, unless the lowest bed should be regarded as between this and the Clinton. The veins of Limonite, mixed with oxide of manganese, are later than the Lower Carboniferous, and constitute here as in the Cobequids a secondary product of the decomposition of the carbonate of iron contained in the ankerite and spathic iron of the Cobequid series.

IRON ORE BED. WEBSTER LOCATION.



a. drift. *b.* slaty rock. *c.* iron ore.

NOTES ON FOSSILS.

A few of the species observed are new, and concerning others new facts were brought out in the examinations made. The more important of these points are referred to below.

Chaetetes or *Stenopora* and *Cladopora.*—Two branching corals referable to these genera are very abundant in the East River beds, and the former also occurs plentifully at Arisaig. The former is a coral of the family *Chaetetidæ*, very closely resembling *S. fibrosa*, but the specimens are not in such a condition as to permit a close comparison. The latter is found only in the state of casts, and is a large-celled species resembling *C. fibrosa* of Hall.

Stricklandinia Billingsiana, n. s.

This is a large shell, 6 centims. in breadth and 4 in length, with a pointed beak and the sides spreading at an angle of about 120° to the broadly rounded lateral corners, which are united by a nearly straight margin. The surface presents unequal lines of growth, and in the middle of the dorsal valve is a low flat ridge with a slight furrow in the centre. The ventral valve has a corresponding flat sulcus. This shell is closely allied to *L. Davidsoni*, Billings, from the Upper Silurian of Gaspé, but is much broader in form.

Strophomena Gilpini, n. s.

Shell, when full grown, nearly an inch in diameter; length and breadth nearly equal; hinge line equal to breadth; valves little elevated; hinge area narrow. Surface marked with numerous fine radiating elevated lines, between which others are introduced as they diverge from the beak. When the surface is well preserved microscopic concentric striæ are seen to cross the radiating lines, and when the outer surface is removed the structure of the shell appears punctate. Muscular impressions oval, elongate and narrow. This shell is very abundant near the Sutherland River ore-bed. It appears to differ from any described American species, but in general form and the style of the muscular impressions resembles *S. ornatella* of Salter from the Upper Ludlow of Britain, though it has finer and sharper superficial sculpture.

Rhynchonella, sp.

In the upper bed of iron ore one of the most frequent shells is a simply ribbed *Rhynchonella*, somewhat resembling *Rh. vellicata* of Hall, but too much distorted and too imperfectly preserved to enable it to be determined with certainty.

Discina, sp.

A small elevated smooth *Discina*, marked only with very delicate lines of growth and near in form to the more elevated varieties of *D. oblongata*, Portlock, from the Middle Silurian of England.

Megambonia cancellata, Hall.

Perfect specimens of this beautiful little shell show that the right valve is flatter than the left, and destitute of the cancellated markings, having only concentric lines. When the valves are closed the basal sulcus has very much the aspect of a byssal aperture. These characters would ally this shell with *Aviculidæ* rather than with *Arcadæ*.

Avicula lamellosa, n. s

Hinge line somewhat longer than the breadth of the shell, and about equal to its length. Left valve tumid, right valve less so, umbones appressed, base broadly rounded, anterior wing short, but decidedly separated from the body of the shell, posterior wing much larger. Surface smooth, but ornamented with concentric thin raised lamellæ, which are continuous over the wings and body, and are elegantly waved, becoming distant from each other on the lower side. Largest specimen 3 centim. long, 3·5 broad. At first sight this species resembles *A. equilatera* of Hall, but is quite distinct in form and markings.

Avicula, sp.

A single left valve of a well-characterised species with the anterior wing nearly as broad as the posterior, and both flat and smooth, or with microscopic concentric lines on the posterior one. Body of the shell with about 15 radiating ribs, crossed by obscure concentric ridges. I had at first regarded this shell as a variety of *A. Honeymani* of Hall, but the anterior wing, when exposed, showed it to be altogether different. I find it difficult to distinguish the last-named species from *A. emacerata* of Hall, as some specimens show radiating striæ on the posterior wing, and otherwise approach to that species.

Pteronitella curta, Billings.

More perfect specimens of this shell enable me to add to Mr. Billings'* description, that the left valve is considerably more convex than the right, and ornamented with concentric, crowded, raised lamellæ. There are two muscular impressions, the anterior small, oval and near the beak, the posterior large and round.

Murchisonia, sp.

In addition to *M. Arisaigensis* and *M. acicula*, which are common on the East River, there is a third species, much less elongated than the former, and with a single revolving band in the middle of the body whorl. The specimens are not very perfect.

Holopea, sp.

A species not distinguishable from *H. sub-conica* of Hall from the L. Helderberg.

Platyceras, sp.

A small but beautifully perfect specimen of a conical and somewhat pyramidal Platyceras, with slight plications on one side. It is not distinguishable from young shells of *P. pyramidatum* of Hall from the Lower Helderberg; and is the only shell of this type I have seen in Nova Scotia.

Orthoceras Pictoense, n. s.

Transverse section oval, perhaps partly a result of pressure. Chambers narrow, 8 in an inch in a specimen 1·5 inch in greatest diameter. Shell scarcely tapering in five inches. Surface when perfectly preserved with delicate longitudinal striæ. Siphuncle not well seen but apparently inflated in the chambers. This is seemingly a representative in our Upper Silurian of *O. bullatum* of England.

Orthoceras (allied to *O. Ibex*).

This species has long been known to me from Arisaig, and I have specimens also from the East River, but not sufficient to make absolutely certain its identity or difference.

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* Palæozoic Fossils of Canada.

Cyrtoceras, sp.

Two species of this genus occur in the East River collections. One is not distingutshable from the *C. subrectum* of Hall (L. Held.) The second is flattened laterally, distinctly bent, the septa one-third centim. distant, in a specimen one centim. in diameter.

Cornulites.

Shells of this species are very abundant in the East River beds. Hall referred the Arisaig specimens to his species *C. flexuosus;* but from their more slender form named them variety *gracilis.* At the East River the majority of the specimens are of the Arisaig type, but some more robust. There are however others more slender than any found at Arisaig. Specimens 1.3 centimetre in length are only 1 millimetre in breadth at the large end, so that from their slenderness they might be mistaken for *Tentaculites*, though the annulations are those of *Cornulites.* But for the apparent connecting forms, these slender specimens might be regarded as types of a distinct species.

Trilobites.

There appear to occur at the East River no less than three species of *Homalonotus.* The most common is *H. Dawsoni*, Hall, and the others are known to me only by fragments. One has much more numerous annulations on the pygidium than that above named, the other has a nearly smooth pygidium, with about twelve very flat annulations on the axis, and resembling that of *H. vanuxemii*, Hall, from the Lower Helderberg. The East River collections also add an *Acidaspis* to the Upper Silurian fauna of Nova Scotia; but the single specimen found is unfortunately too imperfect for description.

NOTE.—For information as to the economic geology of this district, I may refer to "Acadian Geology," and to a valuable Report on the "Mines and Mineral Lands of Nova Scotia," by E. Gilpin, A.M., F.G.S. (Halifax, 1880.)

(From the Canadian Naturalist, Vol. 9, No. 4.)

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

NOTE ON RECENT CONTROVERSIES RESPECTING *EOZOON CANADENSE.*

By Principal Dawson, LL.D., F.R.S., &c.

In a recent article, published in the *American Journal of Science*, I have remarked that

" *Eozoon Canadense* has, since the first announcement of its discovery by Logan in 1859, attracted much attention, and has been very thoroughly investigated and discussed, and at present its organic character is generally admitted. Still its claims are ever and anon disputed, and as fast as one opponent is disposed of, another appears. This is in great part due to the fact that so few scientific men are in a position fully to appreciate the evidence respecting it. Geologists and mineralogists look upon it with suspicion, partly on account of the great age and crystalline structure of the rocks in which it occurs, partly because it is associated with the protean and disputed mineral Serpentine, which some regard as eruptive, some as metamorphic, some as pseudomorphic, while few have had enough experience to enable them to understand the difference between those serpentines which occur in limestones, and in such relations as to prove their contemporaneous deposition, and those which may have resulted from the hydration of olivine or similar changes. Only a few also have learned that *Eozoon* is only sometimes associated with serpentine, but that it occurs also mineralized with loganite, pyroxene, dolomite, or even earthy limestone, though the serpentinous specimens have attracted the most attention, owing to their beauty and abundance in certain localities. The biologists on the other hand, even those who are somewhat familiar with foraminiferal organisms, are little acquainted with the appearance of these when mineralized with silicates, traversed with minute mineral veins, faulted, crushed and partly defaced, as is the case with most specimens of *Eozoon*. Nor are they willing to admit the possibility that these ancient organisms may have presented a more generalized and less definite structure than their modern successors. Worse, perhaps, than all these, is the circumstance that dealers and injudicious amateurs have intervened, and have circulated specimens of *Eozoon*, in which the structure is too imperfectly preserved to admit of its recognition, or even mere fragments of serpentinous limestone, without any structure whatever. I have seen in the collections of dealers and even in public museums, specimens labelled "*Eozoon Canadense*," which have as little claim to that designation as a chip of limestone has to be called a coral or a crinoid." *

These statements were called forth by the appearance of a learned and well illustrated paper, disputing the animal nature of *Eozoon*, by Prof. Karl Moebius of Kiel, and in which, on the evidence of several specimens given to him by Dr. Carpenter and myself, he assumes that he has "investigated more closely and described more minutely" than any other naturalist, its forms and structures, and that by his labours *Eozoon* has been "successfully eliminated from the domain of organic bodies."

Since the appearance of this memoir, and of my criticism upon it, Moebius has published in the same Journal a reply, which has appended to it a note by the principal editor, closing the controversy in so far as that Journal is concerned, by stating that the editor had pledged himself that no rejoinder would be permitted. This, of course, excludes the advocates of the animal nature of *Eozoon* from any farther argument, in so far as the principal organ of scientific opinion in the United States is concerned; and it is partly for this reason that I appear at present in the attitude of a defender of *Eozoon* on its own soil, instead of, as heretofore, carrying the war into the enemy's country.

Still later than this reply of Moebius, are two additional papers of still more remarkable character. For, while Moebius is content to take up a purely negative position, these undertake to account for the structures of *Eozoon* by other causes than that of animal growth, and by causes altogether inconsistent with one another. The first of these is an abstract of a memoir "On the origin of the mineral, structural and chemical characters of Ophites and related rocks," presented to the Royal Society of London by Professors King and Rowney. The second is a quarto pamphlet of 96 pages with 30 plates, by Dr. Otto Hahn, entitled "Die Urzelle,,' the "Primordial cell."

I confess I do not regard either of these papers as of any scientific value, in so far as *Eozoon* is concerned, but as they are at least bold and confident in their tone, and emanate from quarters which may be supposed to give them some little influence, I think it well to notice them along with the reply of Prof. Moebius.

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* Amer. Jour. of Science. March, 1879.

Moebius has thought proper to take advantage of the security guaranteed to him by the Editor of the American Journal, to reply to my courteous and somewhat forbearing criticism, in a manner which relieves me from any obligation to be reticent as to his errors and omissions. I shall, however, confine myself to those points in his rejoinder which seem most important in the interest of scientific truth.

1. With reference to the geological and mineral relations of *Eozoon*, I cannot acquit Moebius of a certain amount of inexcusable ignorance. More especially, he treats the structures as if they consisted merely of serpentine and calcite, and neglects to consider those specimens which, if more rare, are not less important, in which the fossil has been mineralised by Loganite, Pyroxene and Dolomite. If he had not specimens of these, he should have procured them before publishing on the subject. He neglects also to consider the broken fragments of *Eozoon* scattered through the limestones, and the multitudes of *Archæospherinæ* lying in the layers of deposit. Nor can I find that he has any clear idea how the structures of *Eozoon* could have been produced otherwise than by living organisms. Still farther, he makes requirements as to the state of preservation of the proper wall and canal system which would be unfair even in the case of Tertiary or Cretaceous *Foraminifera* injected with Glauconite, how much more in the case of a very ancient fossil contained in rocks which have been subjected to great mechanical and chemical alteration.

2. In his reply he reiterates the statement that *Eozoon* is so different from existing *Foraminifera*, that, if this is a fossil, we must divide all organic bodies into "1. Organic bodies with protoplasmic nature (all plants and animals); and 2. Organic bodies of Eozoonic nature (*Eozoon*, Dawson)." Without referring to the somewhat offensive way in which this is stated, I need only say that Dr. Carpenter has well replied that the structures of *Eozoon* are in no respect more different from those of modern *Foraminifera* than those of many other old fossils are from their modern representatives. All palæontologists know, for example, that while we cannot doubt that *Receptaculites*, *Archæocyathus*, and *Stromatopora* are organic, and probably Protozoan, it has proved most difficult to correlate their structures with those of modern animals.

3. I took occasion to mention certain errors of Prof. Moebius, due to his limited information on the subject of which he treats. He admits two of these, which were particularly pointed out, but taunts me with not producing others. This, however, would not have been difficult had I been disposed to enter in detail into a task so ungracious. Another example may be taken from his plate XXXV, in which he represents together, and obviously for comparison, portions of the pores or tubuli of the modern *Polytrema*, and an imperfect fragment of the proper wall of *Eozoon*, and this more especially, as appears in the text, to show the comparative fineness of the latter. But the specimen of *Eozoon* is magnified only 75 diameters, while that of *Polytrema* is magnified 200 diameters, or in the proportion of 5625 to 40,000. Again he has affirmed and repeats in his reply that the casts of the canal systems of *Eozoon* do not present cylindrical forms but are "*flat* and *irregular* branched stalk-like bodies." If they appeared so to him, he must have possessed most exceptional specimens. Some canals, especially the larger, no doubt have flattened forms, particularly at their points of bifurcation; but this is comparatively rare, more especially in the vastly numerous minute canals which are more frequently filled with dolomite than with serpentine. I have indeed been able to detect only a few out of very numerous specimens in which the majority of the casts of canals are not approximately round in cross section, even in the case of the larger canals. It is a question also if some flattening may not be due to pressure; and there are flat stolon-like tubes which can scarcely be called canals.*

It occurs to me here to remark that Moebius seems to have overlooked the extremely fine canals injected with Dolomite that fill the upper and thinner calcite walls of the better preserved specimens, and which in the thinner walls are nearly as fine as the tubuli of the proper wall, into which in many cases they almost insensibly pass where these last are themselves filled with dolomite. Possibly these structures have not been present in his specimens, or may have been destroyed or rendered invisible by his methods of preparation, and if so this would account for some of his conclusions. These fine canals are best seen in well-preserved serpentinous specimens free from chrysotile veins, and etched with very dilute nitric acid. They have scarcely been done justice to in any of the published figures either of Dr. Carpenter or myself, and do not appear in those of Prof. Moebius.

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* The forms of the canals are perhaps best seen in decalcified specimens; but Mr. Weston, who has done so much toward this investigation, has managed to cut slices so accurately at right angles to the general course of groups of canals, as to show their round cross sections with great distinctness.

4. In reply to my objection that he has confounded the proper wall of *Eozoon* with veins of chrysotile, and that both are represented in his figures, he challenges me to point out which of the latter are chrysotile and which proper wall. Of course doing so will be of little importance to the argument, but I may indicate his figs. 18, 43, 44 and 48 as in my opinion taken from portions of proper wall, and fig. 45 seems to show the proper wall along with chrysotile. I may farther now point out to him that even Profs. King and Rowney in their recent paper admit that the proper wall is not continuous chrysotile, but consists of "aciculæ separated by calcareous interpolations." though they try to account for this structure by complicated changes supposed to have occurred in veins of chrysotile subsequently to their deposition.

In truth, the chrysotile veins cross all the structures of *Eozoon*, and those specimens are best preserved which have suffered least from this subsequent infiltration of chrysotile into cracks formed apparently by mechanical means. This has been amply shewn in figures which I have already published, but I have now still more characteristic specimens which I hope may yet be engraved.

5. Prof. Moebius sneers at my statement that when the proper wall of *Eozoon* is merely calcareous and not infiltrated, its structures are invisible, and that in many cases it has become opaque, while in thick slices its structure is always indistinct; but he should know that this is the case with all fine organic tubuli or pores in fossils penetrated with mineral matter, and eminently so with fossil Nummulites, as the researches of Carpenter have long ago demonstrated, and as any one possessing slices of these fossils can see for himself. I may add that in some decalcified specimens in my possession, where the proper wall has been wholly of calcite, it is indicated merely by an *empty band* intervening between the serpentine cast and the supplemental skeleton filled with casts of canals.

6. Lastly, he seems to think that no offence should be taken at his insinuation that the figures printed by Dr. Carpenter and myself are idealized or untruthful representations, and he repeats the accusation in the following terms: "The individual peculi-

arities of diagrams should not exceed the limits of the known variability of the real specimens, but in the *Eozoon* diagrams of Carpenter and Dawson these limits are exceeded." There could not, I think, be a more plain charge of wilful falsification, and this is made by a naturalist who discusses *Eozoon* without having taken the pains either to study it *in situ*, or to avail himself of the large collections of specimens which exist in England and in Canada. I can only reply that while I have been unable to figure all the peculiarities of the canal systems of this complicated and often badly preserved fossil, I have endeavoured to select the most characteristic specimens; and that my representations are principally, nature-prints, photographs, and camera tracings, some of the latter by artists in no way interested in *Eozoon*. Dr. Carpenter's representations appear to me to be equally truthful. Neither of us have taken the trouble to represent badly preserved or imperfect specimens, any more than we should do so in the case of any other fossil, when better examples were procurable.

In connection with this, Moebius seems to think that in my criticism I should have gone into all the details into which he enters. This was unnecessary, except to expose his principal errors or mis-statements. It could not have been done without publishing a treatise as long and as expensively illustrated as his own; and this I should prefer to do in some other form than as a mere reply to him; and with reference to much larger and more varied collections than those at his command. It is to be hoped that his expectations will be satisfied in this respect by a monograph which Dr. Carpenter proposes to undertake.

He is good enough to add that if I will send him more and better specimens. he will willingly "forgive" me for "disappointing" him and other naturalists. I must say that I cannot purchase forgiveness on such terms, but if he will take the trouble to visit Canada and inspect my collections, he shall have every opportunity to do so.

I think it is only due to the interests of palæontological science to add here, that I attach more blame to the editors of the German publication "Palæontographica," in which his memoir appears, than to Prof. Moebius himself. We have been in the habit of regarding this publication as one in which the matured results of original observers and discoverers are given, and when it devotes 40 costly plates to the labours of a naturalist who is not of this character, in so far as *Eozoon* is concerned, and who has not even studied the principal collections on which other naturalists equally competent have based their conclusions, they incur a responsibility much more grave than if they were merely the conductors of a popular scientific journal, open to cursory discussions of controverted points. They cannot relieve themselves from this responsibility till they shall have published a really exhaustive description of *Eozoon* by some one of the original workers on the subject. This is the more necessary, since if *Eozoon* is really a fossil, its discovery is one of the most important in modern palæontology, and since its claims cannot be settled except by the most full investigation and illustration.

The second paper referred to above contains little that is new, being a re-habilitation of that hypothesis of "Methylosis," or chemical transmutation, which the authors have already fully explained in the Transactions of the Irish Academy and elsewhere. Its bearing on *Eozoon* is simply this:—that if any one acquainted with geological and chemical possibilities can be induced to believe that the Laurentian limestones of Canada are "Methylosed products," which originally "existed as gneisses, hornblende schists, and other mineralised silacid metamorphics," he may be induced also to believe that *Eozoon* is a product of merely mineral metamorphism.

When we consider that these great limestones have been so fully traced and mapped by Sir William Logan and his successors on the Geological Survey; that some of them are several hundreds of feet in thickness and traceable for great distances, that they are quite conformable with the containing beds, and themselves exhibit alternating layers of limestone and d lomite, with layers characterized by the presence of graphite, serpentine, and other minerals, and subordinate thin bands of gneiss and pyroxene rock, the idea that they can be products of a sort of pseudomorphism of gneisses and similar rocks, becomes stupendously absurd, and can only be accounted for by want of acquaintance with the facts on the part of the authors.

To explain the structures of *Eozoon*, however, even this is not altogether sufficient, but we must suppose a peculiar and complex arrangement of laminae, canals. and microscopic tubuli or fibres simulating them, to be produced in some parts of the limestones and not in others; and this by the agency of several different kinds of minerals.

In other words we have to suppose a conversion on a gigantic scale of gneiss into dolomite, limestone, graphite, serpentine, and other minerals, consisting for the most part even of different elements, and this at the same time or by still more mysterious subsequent changes, producing imitations of the most delicate organic forms. The mere statement of this hypothesis is, I think, sufficient to show that it cannot be accepted either by chemists or palæontologists, and it only serves to illustrate the difficulties which *Eozoon* presents to those who will not accept the theory of its organic origin.

Dr. Otto Hahn regards the matter from an entirely different point of view. He has himself visited Canada, has collected specimens of *Eozoon*, and now proposes to effect an entire revolution in our ideas of the palæontology of the Eozoic rocks.

In a former paper he had maintained that *Eozoon* is altogether of mineral origin, that its serpentine is hydrated olivine, and the canal system merely cracks in calcite injected by the expansion of this mineral. This hypothesis he now finds untenable, and he regards *Eozoon* as a vegetable production, or rather as a series of such productions. He regards the laminæ as petrified fronds of a sea-weed, and the canal systems as finer algæ of several genera and species. Not content with this, he describes as plants other forms found in granite, gneiss, basalt, and even meteoric iron, and others found included in the substance of crystals of Arragonite, Corundum and Beryl. All these are supposed to be algæ of new species, and science is enriched by great numbers of generic and specific names to designate them, while they are illustrated by thirty plates representing the quaint and grotesque forms of these objects, many of which are obviously such as we have been in the habit of regarding as mere dendritic crystallisations, cavities, or impurities included in crystals.

Among other curious discoveries the author refers to a plant which he honours me by naming *Photophoba Dawsoni*, and which he discovered in certain "amoeba-like" nodules of flint found in the Silurian of Montreal, and used to adorn the grounds of McGill College. I was puzzled for some time by this, until it occurred to me that at the time of the Doctor's visit some English gravel had been laid on our College terrace, and that several heaps of large irregular flints from this gravel had been gathered in front of the buildings. These had apparently afforded the new plant in question. Some other plants stated to be found in hornblende from Montreal mountain, and in limestone said to be called "fancy stone," are more difficult to account for.

All this plant theory, advanced with the utmost confidence, has no evidence whatever except the assertion of the author and his belief as to the imperfect character of the observations of his predecessors. The following extracts, kindly translated by our colleague Dr. Sommer, will serve to show his mode of treatment:—

"I was convinced of the inorganic nature of Eozoon, or at least of the fact that it could not be an animal. But the fine "canal systems" as Dr. Carpenter had named them, were the source of much anxious thought on my part, and this was necessarily augmented by the following consideration, of which I could not rid myself. "Gneiss is formed by water and therefore a sedimentary rock. Its layers of limestone must contain the first organic enclosures: for, life cannot begin with the silurian rocks." This is a hypothesis, but, like many others that are true, one of which I have not yet rid myself."

"It happened, then, that I had to go to Canada, in consequence of an invitation from the Canadian Government.* I visited Dr. Dawson and thence went to Côte St. Pierre, Petit Nation, there I saw the stratified layers and obtained a great number of pieces of Eozoonic Limestone and of Eozoonic specimens. On my return I examined the material. The result of my examinations I publish here: *the Limestone of the Laurentian Gneiss of Canada, the oldest sedimentary strata of our earth, contains a plant organization belonging to the family of the Algæ.*"

"Till now there have been but few new species established different from the modern; but, I am persuaded, that by continual researches, the number will soon be increased. All these plants, I found enclosed in the *true* "Eozooic Rock," which I shall henceforth call *Eophyllic Limetone.* I shall draw attention to the words that my honorable friend Dr. Dawson also used: "all is not Eozoon!" †

Then follows a description, condensed from Canadian reports, of the Laurentian formation, after which occur the following statements:—

"It is incomprehensible that on looking upon this form, a plant did not occur to the mind, at once. It can only be explained thus: that, at first, when such pieces were not yet discovered, they were so prepossessed by the idea of Foraminifera, that it pervaded all their investigations; while the opponents, (myself included) arrived at once at the obvious conclusion; namely that not being animal it was therefore mineral."

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* Dr. Hahn seems to have been employed on some mission connected with emigration from Germany.

† This, I suppose, refers to the fact that I warned Dr. H. that he would find the greater part of the Laurentian limestone to be destitute of distinguishable Eozoon.

"I found the species which I first called *Eophyllum* in a piece of *Eozoon*, in the first white band of limestone overlying a layer of serpentine; in other words between two layers of serpentine. Then first this question occurred to me: Are not the whole lumps of Eozoon plants? I was forced to yield to the inference after I had exposed, by applying Hydrochloric acid to the limestone, some larger lamellæ which were in connection with serpentinic layers; indeed, the forms are so permanent and so constantly reappearing that they cannot be explained otherwise. Of course with this there was gained the best argument against the animal theory; for, hitherto the discovered species of Algæ have never been found in either stones or shells. This plant belongs to the family of the Algæ. They either rest immediately upon dolomite and gneiss, or, are found in the proper Eophyllous limestone, i.e. in the layers of serpentine limestone, between the large strata of dolomite and serpentine. They are, however, not only to be found in the limestone, but also in the serpentine of the strata. No plants or but few, are found in the thick layers of serpentins which enclose the Eophyllous limestone; certainly none in the lowest. Some of them may be seen with the naked eye, while with the microscope, we come to the smallest conceivable forms. Being replaced by silicates, they may be exposed by the application of acid to the limestone. This done, the plants make their appearance as shining white stems, calyxes, and leaves. In thinly ground plates, they appear a yellowish brown. This, probably, is the reason that Möbius describes their color as being a light brown. In reality, it is the refraction of the light in the opaque masses." *

"There was scarcely ever a more difficult task given to natural science, than the determination of the nature of "*Eozoon*." When I made my first announcement of *Eophyllum* in the "Ausland" I little thought that the large ribbons of serpentine were also plants. I had already half-finished this work after my original plan, when I came across a defective specimen of rock, in which, in consequence of its defectiveness, the serpentine parts were very clearly distinguishable.

"I looked at it over and over again, till it struck me that the sarcode-chambers were nothing but cells of plants. Thus the fate of the microscopist is decided. What others can see with the naked eye he does not see at all. Then came the more difficult part: the examination of the case. Now, I had no more doubt. And in this manner only facts become clear. The ribbons of serpentine which constitute that which is called *Eozoon*, belong to an alga with broad leaves—if the expression is permitted—which radiating from one point arranges itself in regular forms. The basal-cell rests upon serpentine or dolomite. Roots I found only in one case, of which, however, I am not sure. The limestone is the replacing-material. The germ-cells are still visible in it, for in ground pieces for the microscope they still shine through. This may be proved by dissolving the limestone by means of acid. Here the leaves are perfectly covered with germ-cells, the "warzenansatze" of Gümbel. This is still clearer wherever the plant has been altered into dolomite. The brood-cells are then visible without the aid of the microscope. There appear, also, calyx-like cells, clear as water, which have weathered out upon the dolomite.

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* Thus far, the author refers principally to the serpentine casts of the canal system.

"But by far the most beautiful are the limestones in which the plants are changed, partly into serpentine, and partly into mica. The same cells are observed in a spar, changed into copper and malachite, visible to the naked eye. The canal-systems, therefore, of the "intermediate skeleton" are the microscopical plants which, partly. are simply of a limestone nature or have grown firmly upon large algæ, or are deposited there, dead. As I remarked in the beginning, a key to this new creation is, at all events, necessary. I say new, for it is entirely new to our imagination. The microscopical forms constitute this key. Now from these safe premises we may easily come to a conclusion ; but I must here caution against the exclusive use of ground microscopical plates.* It is only by mere accident that, by this means, a view is gained ; hundreds of them may be made, but only a very trained eye can decipher them."

It seems scarcely necessary to criticise the above statements, as it is probable that very few naturalists will be disposed to accept the supposed plants described by Dr. Hahn as veritable species. It may be observed, however, that in regarding the thick plates of serpentine, interrupted, attached to each other at intervals, penetrated by pillars of calcite, and becoming acervuline upward, as fossil algæ, he disregards all vegetable analogies; while in supposing that the calcite is a filling, and that the delicate fillings of canals contained in it are fine thread-like algæ, he equally asserts what is improbable. Farther, no vegetable structure or remains of carbonaceous matter have been discovered in the serpentine. Had he discovered these supposed vegetable forms in the graphite of the Laurentian, this would have been far more credible.

Hahn's paper, however, suggests one or two points of interest respecting *Eozoon*, which have perhaps not been sufficiently insisted on. One of these is the occurrence of rounded "chamberlets" in the calcareous walls. These are his "germ-cells," and they sometimes present the curious character that they are hollow vesicles of serpentine filled with calcite, and when these have been cut across in making a section, and the calcite has been dissolved out with an acid, they present very singular appearances. They may in some cases have been germs of *Eozoon*, or smaller foraminifera of the type of *Archæospherinæ*, overgrown by the calcareous walls. It is farther to be observed, as I have also elsewhere remarked, that the serpentine filling the larger spaces between the calcareous laminæ sometimes shows indications of deposit as a lining of the cells, and in some specimens this lining has not filled the original space but has left a drusy cavity afterwards filled with calcite.

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* If this is intended to apply to Canadian and English students of *Eozoon*, it is quite inaccurate, as they have always employed decalcified specimens as well.

Again, in parts of the canal system, especially when filled with dolomite, there occur little disc-like bodies or trumpet-shaped terminations of canals. These, I fancy, are the calyx-like objects figured by Hahn. Their precise significance is not known, further than that they may represent the expanded ends of canals. Another appearance deserving of notice is the occurrence of portions of specimens of *Eozoon* in which little or no serpentine occupies the chambers. In this case the laminæ have either been pressed close together, or the chambers have been filled with calcite not distinguishable from the walls, in which, however, the casts of groups of canals often occur, and might then be more readily mistaken for algæ than when they occur between laminæ of serpentine.

Lastly, I have recently found in a specimen of *Eozoon*, structures which may possibly indicate contemporaneous plants. I have previously remarked the occurrence of deep pits or cylindrical cavities in some specimens of *Eozoon*, and have supposed that they might be of the nature of oscula. Those now referred to are, however, more definite than any previously observed. They are cylindrical perforations penetrating the whole thickness of the mass, and filled with calcite. One of them is simple, another seems to bifurcate. They are about an eighth of an inch in diameter, and present indications of alternate swellings and contractions. In approaching them the plates of serpentine split into two, and then unite, forming a continuous close wall of sarcode. This proves that these tubes are not perforations of any boring animals. They must be either definite canals penetrating the mass while living, or must represent cylindrical stems of algæ or other perishable organisms, around which the *Eozoon* has grown. As they are only exceptionally seen, the latter supposition is perhaps the more probable. Peculiarities of this kind, to which perhaps heretofore too little attention has been given, are of some importance with reference to the controversies respecting *Eozoon*.

It may be said, in connection with the attacks in question, that if *Eozoon* is an object of which so many and strange explanations can be given, it is probable that no certainty whatever can be attained as to its real nature. On the other hand it is fair to argue that, if the opponents of its animal nature are driven to misrepresentation and to wild and incoherent theories, there is the more reason to repose confidence in the sober view of its origin, consistent with its geological relations and microscopic characters, which has commended itself to Carpenter, Gumbel, Rupert Jones, Sterry Hunt, and a host of other competent naturalists and geologists. For my own part the arguments adduced by opponents, and the re-examination of specimens which they have suggested, have served to make my original opinion as to its nature seem better supported and more probable; though of course I would be far from being dogmatic on such a subject, or claiming any stronger conclusion than that of a reasonable probability, which may be increased as new facts develop themselves, but cannot amount to absolute certainty until the discovery of Laurentian rocks in an unaltered state shall enable us to compare their fossils more easily with those of later formations.

In point of fact, the evidence for the organic nature of a fossil such as that in question, is necessarily cumulative, and depends on its mode of occurrence and state of mineralisation, as well as on its general form and microscopic structure; and it is perhaps hopeless to expect that any considerable number of naturalists will be induced to undertake the investigations necessary to form an independent opinion on the subject. It may be hoped, however, that they will fairly weigh the evidence presented, and will also take into consideration the difficulty of accounting for such forms and structures except on the hypothesis of an organic origin.

Regards of JWDa

(*From the Canadian Naturalist. Vol. X. No.* 1.)

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA

PALÆONTOLOGICAL NOTES.

By J. W. Dawson, LL.D., F.R.S.

I. A New Species of Piloceras.

(Figs. 1, 2.)

This genus was established by Salter, in 1858,* for a very curious shell found in Scotland, in the Durness Limestone, one of the lowest members of the Lower Silurian or possibly within the limits of the Upper Cambrian. Salter found in this limestone two species of the genus, but one was too imperfect for description. The typical species *P. invaginatum* he regarded as the shell of a cephalopod mollusk allied to *Orthoceras*, but of very simple structure, having the chamber and siphuncle united into one organ. His definition of the genus was in these words: "siphuncle and septa combined, as a series of conical concave septa which fit into each other sheathwise."

In 1860, Billings described, in the *Canadian Naturalist*, † a species from the Calciferous Formation of Belleisle, under the name *Piloceras Canadense.* The specimens showed that the part described by Salter was not the external shell, but only the siphuncle, and that the shell, when complete, must have included a chambered portion surrounding this enormous siphuncle, which thus corresponded to the great siphuncle of the Lower Silurian shells known as *Endoceras.* Having thus ascertained the existence of external chambers, Billings supposed that the sheathing divisions of the interior described by Salter had been filled with a solid deposit of carbonate of lime, so that this curious shell would seem to have had a sinker as well as a float. The specimen now to be described shows that this was probably an error, and that the shell had a double series of chambers, and was thus not a very simple form, as supposed by Salter, but really a shell of great complexity. Billings afterwards described three additional species from the Quebec group of Newfoundland.

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* Journal of Geological Society of London, Vol. XV.

† Vol. V.

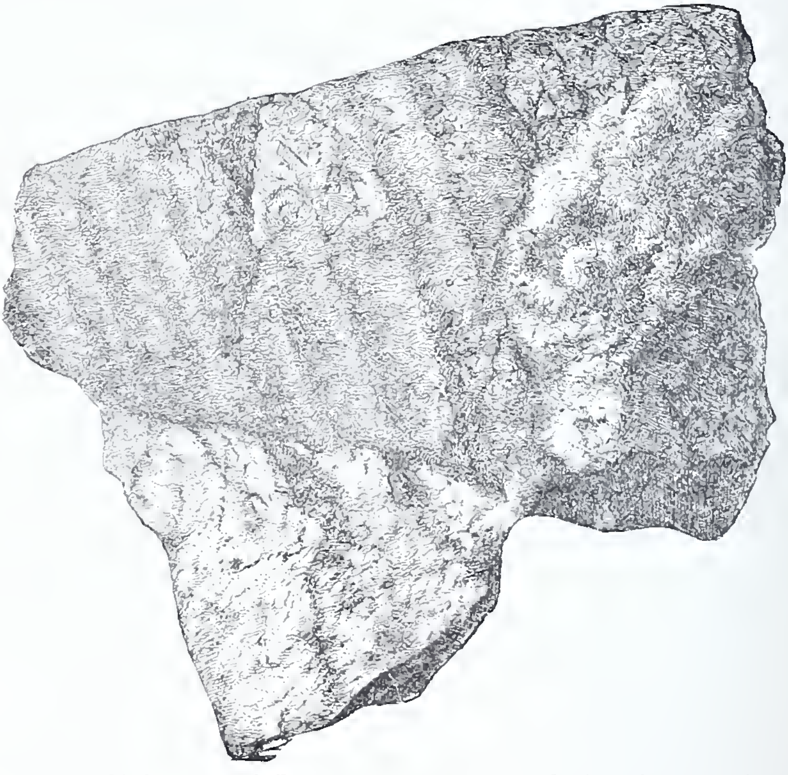

Fig. 1.—Siphuncle of *Piloceras amplum*, natural size, from a photograph. The chambers are seen in part on the stone at the lower side, but have not been correctly given by the engraver.

The present specimen was found in the Calciferous sandstone, a few miles south-east of Lachute, by Mr. Macpherson, a member of my class in Geology, in the course of an excursion to that neighborhood last autumn. It represents a species quite distinct from those described by Salter and Billings—probably an adult individual—and it illustrates in a very interesting manner the complex structure of this remarkable group of shells.

The siphuncle, which wants a portion of the apex, is a flattened cone, which, when complete, must have been about 5½ inches in length, and 2½ in its greatest diameter. It is marked, in the portion preserved, with about twelve diagonal ribs, indicating the lines of attachment of the partitions of the external shell, of which only portions of a few remain attached to the surface at one side. The lower part of the shell is divided by a vertical partition crossing its longer diameter. At the top this splits into a flattened cone, somewhat flatter than the siphuncle itself, and more obtuse, so that at the top it joins and unites with the rim of the siphuncle. The space below this inner cone is that supposed to have been solid; but in the present specimen it is filled with calcite, showing that it must have been an enclosed space. Farther the vertical partition presents, in section,

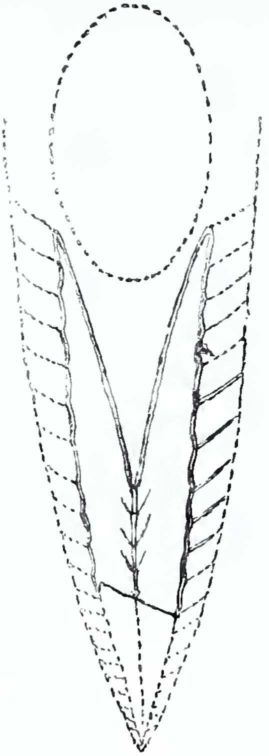

Fig. 2.—Transverse and restored vertical sections of *Piloceras amplum* reduced. The upper figure shows the proportions of the cross section. The lower figure is a section in the direction of the shorter diameter, showing the conical siphuncle, the siphuncular cavity, with remains of partitions, and the external chambers. The dotted lines are restored portions.

a series of swellings or ridges, and to these are attached the remains of what seems to have been membranous partitions, which must have formed successive interior cones as the siphuncle grew in size, terminating in the final one, which became completely calcified.

It would thus appear that the shell had a wide conical siphuncle which, as it grew in height, it partitioned off, with flattened cones within. The effect would be to give protection to whatever part of the body extended back into the siphuncle, to give great strength to the shell, and to form a double series of air chambers, that within the outer shell and that in the apex of the conical siphuncle, by which great buoyancy would be secured.

As Salter has already remarked, this shell has affinities with such shells as *Cameroceras* and *Endoceras*, though in magnitude of siphuncle it exceeds these types, as well as possibly in the property of possessing a double series of air cells. It is, however, not improbable, from the manner of the filling of the partitioned parts of the siphuncle of *Endoceras*, that this also was hollow in the living state.

I would propose for the present species the name *Piloceras amplum*, with reference to the great width of the siphuncle. Its description will be as follows :

Length of siphuncle, 12 centimetres ; longest diameter at the top, 6 centimetres : shorter diameter, 3.5 centimetres ; greatest angle of divergence of siphuncle, about 27°. Siphuncle annulated with raised lines, marking the attachment of the septa of the exterior shell. These lines are inclined to the axis of the shell at an angle of about 20°. They are, however, slightly curved and on the dorsal (?) side of the shell bend slightly downward. The internal cone of the siphuncle is 5 centimetres in depth. It is flatter than the siphuncle, ending at the apex in an edge, which is attached to a central shelly plate crossing the lower part of the siphuncle. This plate shows, at intervals, slight projections giving rise to delicate internal cones apparently membranous. The space between the inner cone and the wall of the siphuncle must have been empty and closed, as it has been filled not with the surrounding coarse dolomite, but with calcite, introduced by infiltration. Whether the siphuncle was central or lateral does not appear. There are, however, distinct marks of the partitions of the chambers all around it.

II. Saccammina ? (Calcisphæra) Eriana.

(An Erian Rhizopod of uncertain affinities.)

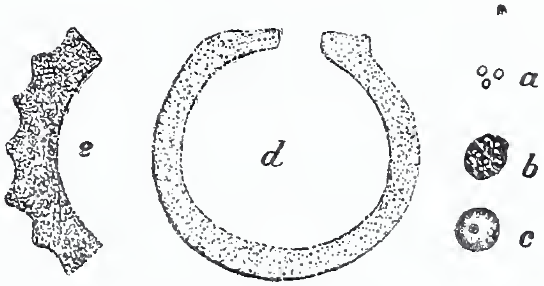

Fig. 3.—*Saccammina Eriana.* (*a*) natural size ; (*b*) magnified, showing sculpture ; (*c*) magnified, showing aperture ; (*d*) section magnified, showing aperture ; (*e*) section of portion of wall more magnified, showing structure.

Several years ago, specimens were sent to me by my friend Dr. Newberry, of New York, of a curious organism from the Devonian (Corniferous) limestone of Kelly's Island, near Sandusky, Ohio. They are minute globular bodies, one millimetre in diameter, and occur in great numbers in light gray limestone containing *Stromatopora*, crinoidal joints and corals, as well as multitudes of minute organic fragments. The exterior surface of the specimens is dull or granular in aspect, and either smooth or marked with slight spiral ridges, giving an appearance which at first sight suggests a resemblance to the spore-cases of *Chara*. On microscopic examination, they are found to be hollow spheres filled with calcite introduced by infiltration, having one small aperture ; and the test or wall of the sphere presents a granular appearance as if composed of fine calcareous grains. Understanding that Dr. Newberry desired a note for publication in his Reports on the Survey of Ohio, I prepared and sent to him the following description, which, however, I have not yet seen in print :—

"*Saccammina Eriana.*—Test globular, about one millimetre in diameter, with one aperture. Wall composed of minute calcareous grains, smooth interiorly, on the outside smooth, irregular or fluted longitudinally. Corniferous limestone near Sandusky. Collection of Dr. Newberry.

"This little organism occurs in great numbers in whitish granular limestone, associated with fragments of crinoids and corals. Its test appears to be composed of very minute calcareous grains, and it can scarcely be anything else than a Rhizopod, probably allied to the modern *Saccammina globosa*, or to the Carboniferous *S. Carteri*, though much smaller than either, and differing in its tendency to external ornamentation. It is of course possible that a test of this kind might belong to an animal of very different character from *Saccammina*, but in the present state of knowledge of such forms, I think it quite justifiable to refer it to this genus."

In the conclusion of the above note I referred to the chara-like form of the test, and to its entire difference of structure from any vegetable organism. At a subsequent date I obtained additional specimens from Mr. Walker, of Hamilton, Ontario; and in my paper on *Stromatoporidæ*, published in the Journal of the Geological Society in 1879, I referred to it, under the above name, as associated with *Stromatopora*, and sometimes overgrown by its layers.

In the course of last summer, I received from Prof. Williamson, of Manchester, Part X of his valuable Memoirs on the Organisation of the Plants of the Coal Measures, and was surprised to find my little fossil noticed therein, with a new name and in quite a new connection. It appears that some bodies of similar appearance, but much smaller, had been found by Prof. Judd in Carboniferous limestone in Wales, and that they had been referred to the group of Radiolarians. This reference was disputed, apparently on good grounds, by Prof. Williamson. He had examined them, under the impression that they might be of vegetable origin, but finally had supposed it more likely that they were animal and foraminiferal, and had assigned to them the non-committal name of *Calcisphæra*. They had also, in the course of the discussion as to their nature, raised the chemical question whether it was possible that silicious tests like those of Radiolarians could be replaced by carbonate of lime: a change which, though perfectly possible, and sometimes realised in Palæozoic silicious sponges, is in the highest degree improbable in the case of these bodies. In the course of this investigation, Prof. Williamson had received from our mutual friend Mr. H. B. Brady, F.R.S., specimens of the little fossil from Kelly's Island, which, I think, I had sent to him, and these were referred by Williamson to the same genus with the Welsh specimens and named by him *Calcisphæra robusta*. He described the species as follows:

"Each organism is a hollow sphere. The sphere-wall is much thicker in proportion to its diameter than is the case among the Welsh specimens. Externally the transverse section of each sphere presents an undulating outline due to the intersection of prominences and ridges that characterise its surface. Sometimes these surround the entire section, but more frequently they are absent from limited portions of the periphery. Occasionally these ridges may be seen pursuing an oblique direction like the bands crossing the nucules of a *chara*. The central cavity is always occupied by crystalline infiltrated carbonate of lime. Though the sphere-wall often exhibits a granular texture, I discover a radiating structure in a sufficient number of the specimens to convince me that in this respect they have closely resembled some of the Welsh objects."

This description differs from mine in two important points: (1) It does not recognise the aperture, which is of course not easily observed except when specimens can be completely detached from the matrix. It exists, however, and is surrounded by a slightly flattened space or rudimentary flange. I may add that the possesion of an aperture does not conflict with the filling of the test with clear calcite, as the same substance occupies the spaces between the fragments contained in the enclosing limestone. (2) The supposed fibrous character of the test does not appear in my specimens. They are decidedly granular, even when viewed under high powers, though there is occasionally a tendency to linear arrangement in the constituent grains, perhaps indicating a porous structure. I have examined many specimens both by reflected and transmitted light, and feel confident that there is no truly radiating structure either of tubes or pillars. Farther, the minute grains of the test are similar in size and appearance to the more minute fragments visible in the matrix; and I cannot doubt that the test is granular and arenaceous, though it is of course possible that this granular texture may be a result of re-arrangement of particles in the process of fossilization. This, however, I do not think at all probable.

On the whole, I see no reason to depart from the conclusion that the organism in question is the test of a foraminifer, and this seems also to be the opinion of Williamson and Brady, who are the best possible authorities on such a question.

With regard to affinities, the flange-like orifice suggests relationship to the *Lagenæ*, while the globular form resembles

Orbulina, and the arenaceous character suggests nearness to *Saccammina*, which also approaches most nearly in geological time. The ridged surface is no doubt unusual in arenaceous tests, but a tuberculated surface is found in some, as, for instance, in that from the Challenger dredgings recently described by Brady, under the name *Thurammina papillata*. The name *Calcisphæra* would be unobjectionable, were it not for the difference of structure in the test of the forms referred to this genus, and which on this account appear to me to be possibly of different nature. In the mean time, therefore, I leave the question of name as it stands at the head of this notice.

Note. (March 14, 1881.)—In a letter just received from Mr. H. B. Brady, he says that he knows of no rhizopod test recent or fossil, precisely corresponding to the little Erian fossil above described. He says—"the more I examine your little fossil the more confident I am that it bears no relation to any rhizopod type that I know." It will thus appear that he does not admit its affinity to *Saccammina*, and that he even doubts as to its rhizopodal character.

III. New Devonian Plants from the Bay de Chaleur.

The following notes relate to the examination of plants collected by Mr. A. H. Foord, of the Geological Survey, at Scuminac, opposite Dalhousie, and by Mr. Weston, of the Geological Survey, near Campbellton.

Mr. Foord's collections are from the Sandstones containing *Pterichthys Canadensis* Whiteaves, and other fossil fishes, and which appear in a low anticlinal form overlaid unconformably by a great thickness of red sandstone and conglomerate of the Bonaventure Formation (Lower Carboniferous). The beds seen at this place are characterised by their fauna, as of Upper Erian (Devonian) age.

1. *Archæopteris Gaspiensis*, s. n.

Barren pinnæ densely leafy, with the pinnules broadly obovate and somewhat truncate at the apex, decurrent by a broadish base on the somewhat stout striated petiole, veins forked thrice and strongly curved toward the lower edge. In luxuriant fronds the pinnules are 2.5 centimetres long and 1.8 centimetre broad.

Fertile pinnae with about twelve pinnules, each having a long midrib with about 7 pairs of crowded oblong spore-cases about 3 millimetres in length, pointed or somewhat obtuse at top, straight at the sides and apparently dehiscent at the apex. The midrib projects some distance beyond the spore-cases.

This species differs from *A. Jacksoni*, Dn., in the arrangement of the spore-cases, which are also larger and more oblong, and the barren pinnules are broader. It differs from *A. Hibernicus*, Brongt., in the arrangement and form of the spore-cases and in its shorter pinnæ, with fewer and less obtuse pinnules. It differs from *A. minor*, Lesquereux, in the arrangement of the spore-cases, which in the latter are in groups of three and of larger size, while the barren pinnules are much narrower. The present species resembles *A. Maccoyana*, Goeppert, in the form of the pinnules, but the fructification of the latter species is not known, and it may be merely a varietal form of *A. Hibernicus*. The present species is no doubt that referred to in my report on the Devonian plants of Canada as found in the Gaspé sandstone,* but the fragments known at that time did not enable me to separate it from *A. Jacksoni*. It is for this reason, as well as because the beds in which it occurs at Bay de Chaleur represent the upper part of Logan's Gaspé sandstones, that I have given it the name *Gaspiensis*.

Ferns of this type are characteristic of the Upper Erian on both sides of the Atlantic, and do not occur in the Carboniferous proper; though forms resembling them occur in the lowest Carboniferous beds.

2. *Cyclopteris obtusa*, Lesquereux.

I refer to this species a large and beautiful fern, which is obviously identical with that from the Cattskill of Montrose, Pennsylvania, figured by Lesquereux in the "Coal Plants of North America" (Report of Pennsylvania Survey), pl. 49, fig. 7, and of which I have a specimen in my own collection from the same formation at Franklin, New York.

This species is characterised by very large obovate leaflets decurrent by a long narrow base upon the petiole. Whether it was a pinnate or bipinnate frond does not appear. The veins are fine, curved and several times forked. The terminal leaflet is cuneate and emarginate. Some of the large pinnules are 6 centimetres in length. This fern is referred by Lesquereux to my genus *Archæopteris ;* but as its fructification is not known, and as this forms the most distinctive character of *Archæopteris,* I think it better to leave the species in the provisional genus *Cyclopteris.*

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* Page 487.

One of my plants from the Devonian of St. John is referred to Lesquereux's species *C. obtusa.* The identification was made on the evidence of the figure and description in Rogers' Report on Pennsylvania, which refer to a much smaller fern than the present species, with the pinnules somewhat different in form and attachment. As Lesquereux, however, applies his name to the large species now under consideration, which is certainly distinct from the St. John fern, I must withdraw the name from the latter. In doing so, I may take advantage of a suggestion made by Schimper, who thinks that the St. John species might be placed in the genus *Aneimites.* It may accordingly be renamed *Aneimites obtusa,* which will at least prevent confusion.

Cyclopteris Brownii, Dawson.

(Report on Fossil plants of Devonian and Upper Silurian, p. 48, fig. 172, Journal of Geological Society of London, vols. xvii and xix.—Figures and description.)

This beautiful fern was previously known only from Perry in Maine, where it occurs only rarely and in detached leaves. Mr. Foord's specimens shew its habit of growth in dense clusters of fronds attached to what appears to be a creeping rhizome with slender rootlets. It has evidently been a low-growing species, its flabellate leaves attached by somewhat broad bases to a rootstock probably prostrate. Unfortunately no fructification appears, so that the plant cannot be compared with modern species having the same habit of growth. I may state, however, that the veinlets widen and become more dense in approaching the outer margin of the frond in a manner which seems to indicate that the fructification was marginal, in the manner of the *Pterideæ.*

It seems probable that the fern from the Upper Devonian of Pennsylvania figured by Lesquereux in Fig. VII, p. 50 of the Coal Plants of N. America is identical with this species. He refers it to *Rhacophyllum* of Schimper, with the specific name *R. truncatum,* which will, in this case, be a synonym of *C. Brownii.* The genus *Rhacophyllum* is very loosely defined by

Schimper, and is evidently provisional, including, according to him, young or basal fronds of ferns referred to other genera. As there is no evidence of this in the case of the present species, I see little advantage in removing it from the equally provisional genus *Cyclopteris*, until its fructification shall have been discovered. Should it, however, be considered desirable to remove it from *Cyclopteris*, I would propose for it the name of *Platyphyllum*, for which the characters of this plant as given in the paper above cited and in this note may suffice as generic characters.

Caulopteris (?)

Among Mr. Foord's specimens is one that appears to represent the stem of a small tree fern. It is about one inch in diameter, flattened and showing on the exposed side somewhat reniform scars quincunctially arranged. The best preserved leaf-scars show marks of vascular bundles which suggest the idea that it may have given origin to the petioles of ferns; but there is nothing to indicate whether this stem belongs to either of the species found with it.

Plants from Campbellton.

Mr. Weston's collections are contained in a hard argillaceous sandstone or arenaceous shale resembling some of the beds of the lower part of the Gaspé sandstones, with which the flora also agrees.

The greater part of the vegetable remains collected by Mr. Weston are stems and branches of *Psilophyton princeps* and *P. robustius*, which are very abundant. There are also a few leaves of *Cordaites angustifolia*, and in the same shale with some of these, is a short stem with remains of alternate leaves or branches. This may possibly have belonged to the last named species.

There are also specimens of strobiles, about an inch in length and thickly covered with scales or spore-cases which appear to be in two rows, but this is probably deceptive and an effect of flattening. They very much resemble the strobiles of *Lycopodites Richardsoni* from Perry, but the scales are thicker and more obtuse. This is probably the fruit of some lycopodiaceous plant, and may provisionally be referred to the genus *Lepidostrobus.*

The beds containing these fossils evidently belong to a lower horizon in the Erian than that containing the fossils collected by Mr. Foord.

ON THE GEOLOGICAL RELATIONS OF THE IRON ORES OF NOVA SCOTIA.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

(*Read before the American Association for the Advancement of Science.*)

By J. W. Dawson, LL.D., F.R.S.

The Iron Ores of Nova Scotia, long neglected, have recently begun to attract the attention of capitalists to an extent in some degree commensurate with their importance. The magnitude and variety of the deposits, the great richness of the ores, their proximity to the Atlantic and to great deposits of coal, are all features which give them very great economic value, and must eventually cause them to take no small part in contributing to the iron supply of the world. My purpose in the present paper is, with the aid of recent researches in which I have been occupied, to give a concise summary of the geological position and mode of occurrence of the principal deposits, and more especially of those facts which have been developed since the publication of my "Acadian Geology."

If we arrange these deposits in the first place under the two heads of *Beds* conformable to the stratification and *Veins*, we shall find that the former occupy three distinct geological horizons—that of the Lower Helderberg or Ludlow in the upper part of the Silurian, that of the Oriskany at the base of the Devonian, and that of the Lower and Middle Carboniferous. The latter occur in altered rocks which may be assumed to be of

Silurian age, in the Lower Carboniferous, and at the junction of these two groups of rocks. We may shortly consider the deposits of these several kinds and ages in their order.

1. BEDDED ORES.

(1) *Great Hematite Bed of the Lower Helderberg Series.*

This, in so far as at present known, is most extensively developed in the vicinity of the East Branch of the East River of Pictou, and on the upper part of Sutherland's River. Here the rocks which rise unconformably from beneath the Carboniferous beds of the Pictou coal-field, consist in great part of gray and olive slates, usually coarse and unevenly bedded, and with occasional calcareous bands, holding the characteristic fossils of the "Arisaig group," a series in Nova Scotia equivalent to the Lower Helderberg of American geologists, though in its specific forms more nearly allied to the English Ludlow than to groups of this age on the great inland plateau of America. These beds are affected with slaty cleavages, highly inclined, much faulted, and folded in abrupt anticlinals, so that their detailed arrangement has not yet been satisfactorily traced. The great ore-band which forms one of the most conspicuous marks for unravelling their complexities, has been traced mainly along two distinct lines of outcrop, both somewhat curved and broken, and which seem to lie on the opposite sides of an anticlinal axis. It has also been recognized in two other localities where it must come up on distinct lines of outcrop, the precise relation of which to the others has not yet been ascertained.

The ore bed is accompanied by a thick band of olivaceous slates, and beneath this there appears hard ferruginous quartzite which Dr. Honeyman compares to the Medina sandstone. Lower than this and possibly unconformable to it are black and greenish slates with bands of quartzite and soft chloritic and nacreous schists which as yet have afforded no fossils. They are associated with hard beds or masses of rock rising into some of the highest eminences, and which have usually been described as trap, but which seem to consist for the most part of an indurated slaty breccia or conglomerate, corresponding very nearly in character to the typical graywacke of the older German geologists. These rocks may be of middle Silurian age, though possibly in part older, and we shall meet with them again in connection with the great vein of specular iron.

The ore-bed where most largely developed attains a thickness of about thirty feet, and in places where it has been opened up by exploratory works, it has been found to afford from ten to twenty feet in thickness of good ore. This ore is a red hematite, sometimes compact and laminated, but more frequently of an oolitic character occasioned by the arrangement of the peroxide of iron in minute concretions enveloping grains of sand. By the increase of these silicious grains it passes in the poorer portions into a sort of ferruginous sandstone. Similar beds of fossiliferous ore are well known to occur in the Clinton group of New York and Pennsylvania, and Prof. Hall informs me that they are found also in the Lower Helderberg series of New York.

Along the different lines of outcrop above referred to, this bed has been traced for several miles, and being of a hard and resisting character, it rises into some of the higher elevations of the country. Though not one of the richest ores of the district, its great quantity and accessibility render it highly important for practical purposes. The analyses made of it show a percentage of metal varying from 43 to 54 per cent. The foreign matter is principally Silica, and the proportions of Phosphorus and Sulphur are small—one of the specimens analyzed affording none whatever, another .22 Phosphoric Acid and .29 Sulphur. These analyses were made at the instance of Mr. E. A. Prentice, now organizing a company to work this and other deposits in the district. The principal exposures of this bed are distant only twelve miles from the great collieries of the East River of Pictou, and less than ten miles from the Pictou and Halifax Railway. This deposit was first described by Mr. R. Brown in Haliburton's History of Nova Scotia, 1829, and subsequently by the writer in Acadian Geology. More recently exploratory works have been carried on and a practical report made by Mr. G. M. Dawson, Associate of the School of Mines, London; and the bed has been traced and collections of its fossils made by Mr. D. Fraser of Springville.

(2) *Hematite and Magnetic Iron of Nictaux and Moose River.*

This deposit takes us to the other extremity of Nova Scotia, and brings us a stage higher in geological time, or to the period of the Oriskany Sandstone. It would indeed appear that the conditions of ore-deposit so marked in Eastern Nova Scotia in the upper Silurian, were continued in the western part of the Province into the Devonian. In many specimens of the Nictaux ore the chief apparent difference as compared with that of Pictou is in the contained species of fossils.

Where I have examined this bed, it appears to be six feet thick and enclosed in slaty rocks not dissimilar from those associated with the Silurian ore of Pictou. Recent explorations at Nictaux are said to have developed extensions of this deposit; but I have no details of these. As rocks of the Arisaig group are known to underlie the Nictaux beds, it is not impossible that additional beds of ore may be found in these. The normal condition of the iron of the Nictaux bed is that of peroxide; but locally it has lost a portion of its oxygen and has become magnetic. This I believe to be a consequence of local metamorphism connected with the immense granite dikes which traverse the Devonian rocks of this region.

The Nictaux ore is more highly fossiliferous than that of Pictou, and contains a larger proportion of Phosphate of Lime. In the attempts hitherto made to work this ore, the distance from coal has been a main disadvantage, but the construction of the Windsor and Annapolis railway has diminished this. The Devonian beds holding this bed are described in "Acadian Geology." An analysis of a specimen made many years ago gave 55 per cent of iron.

(3) *Bedded Ores of the Carboniferous System.*

The most remarkable of these is a bed of crystalline *Spathic iron* or Siderite, occurring in the Lower Carboniferous series, near Sutherland's River in the County of Picton. As described by Mr. G. M. Dawson, who prosecuted works of exploration in it last year, it is a conformable bed, occurring in the Lower Carboniferous red sandstones, and varying from six feet six inches to ten feet six inches in thickness. It is accompanied with smaller bands of the same mineral, and at no great vertical distance from it is a bed of gypsum. Its mode of occurrence is on the whole not dissimilar from that of the non fossiliferous sub-crystalline limestones which occur in some parts of the Lower Carboniferous series associated with the gypsum. This ore is a true Spathic Iron, granular and crystalline in texture, and when unweathered of a light gray colour. It affords from 42 to 43 per cent. of iron and contains from 2 to 8 per cent. of manganese. This bed is only four miles distant from the "Vale" colliery, and is intended to be worked in association with the Hematite already described, and with the other ores on the East River of Pictou possessed by the same proprietors. From the Report of Mr. Andrews on the second geological district of Ohio, it would appear that similar beds, though on a smaller scale, occur in the Lower Carboniferous series of that State. In Nova Scotia this bed is at present altogether unique.

Clay Ironstones occur in many parts of the Nova Scotia coal-field. In the workings of the main seam of the Albion Mines, Pictou, considerable quantities of nodular black ironstone are extracted, and will, no doubt, be utilized. In the beds under the main seam there are also clays rich in ironstone concretions. Beds with ironstone balls also occur in the measures north of the New Glasgow conglomerate, and one of these is remarkable for the fact that the nodules were found by Dr. Harrington to contain nuclei of Blende, a mineral otherwise unknown in the carboniferous of Nova Scotia. No attention has yet been given to these ores as sources of iron, but it may be anticipated that a demand for them will arise in connection with the richer ores in the older formations.

II. Veins of Iron Ore.

(1) *Great Specular Iron Veins of the Silurian Slates and Quartzites.*

In a paper on the metamorphic and metalliferous rocks of Eastern Nova Scotia in 1848,* I mentioned the fact that the inland series of metamorphic rocks (bounding the coast series now known as the gold-bearing series) and believed to be of Upper or Middle Silurian age, abound in veins of specular iron, associated with spathic iron and ferruginous dolomite, and occasionally with metallic sulphides, and I described some of these deposits. In the country eastward of Lochaber Lake, where this same formation occurs, not only are numerous small veins of specular iron and carbonate of iron found in it, but a rich vein of Copper Pyrites, noticed in "Acadian Geology," has recently been opened up and found to be very valuable.

In most parts of the region these iron veins, though very numerous, are of trifling thickness; but in two localities they are known to attain to gigantic dimensions, rendering them of great economic importance.

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* Journal of Geological Society of London.

The earliest known of these was the great vein of the Acadia mine in the Cobequid mountains, discovered by the late Mr. G. Duncan, and on which I reported in 1845. These hills consist on their southern side of parallel bands of olive and black slate with beds of quartzite, all very highly inclined. The iron vein is a great irregular fissure, extending for many miles parallel to the bedding, and apparently accompanying a band of quartzite. It contains in addition to crystalline and often micaceous Specular iron and Magnetic iron, large quantities of a rich earthy red ore, which from the crystalline planes which it presents, would seem to have been a Carbonate of Iron decomposed and oxidised. These iron ores are associated with large quantities of a crystalline ferruginous Dolomite, allied in composition to Ankerite. This may be regarded as the veinstone to which the iron ores are subordinate, and which in the thinner parts of the vein occupies nearly its whole breadth. At the outcrop of the vein it is in some places weathered to a great depth into a soft and very pure yellow ochre. Small quantities of sulphides of iron and copper and of sulphate of barium are occasionally present. In addition to the above, which may be regarded as the primary contents of the vein, there occur in some parts of it secondary deposits of concretionary Limonite, which have of late years afforded a very large part of the ore smelted by the Acadia Company.

In some places the thickness of this vein has been found to be 150 feet, with intercalated masses of rock, but it is very irregular, diminishing occasionally to mere strings of ankerite. It is remarkable that in the Cobequid mountains, which are cut by transverse ravines to the depth of about 300 feet, the vein does not appear to be well developed in the bottom of the ravines, but only in the intervening heights At first I was disposed to account for this by supposing that the deposit is wedge-shaped, diminishing downward; but I have more recently been inclined to believe that the large development of the vein is dependent on differences in the containing rocks which have rendered them harder and more resisting at the points of such greater developments.

With respect to the age of these beds, they must be older than the Lower Helderberg rocks, which both at the eastern end of the Cobequids and at the East River of Pictou, rest upon them. They are on the other hand probably newer than the auriferous primordial rocks of the Atlantic coast. As they have afforded no fossils their age does not at present seem capable of more precise definition. With regard to the filling of the vein fissures, this, if coeval with the metamorphism of the containing beds or immediately subsequent thereto, would fall between the period of the lower Devonian and that of the lower Carboniferous, or within the Devonian age. The denudation connected with the Lower Carboniferous conglomerates and the fragments contained in these conglomerates, seem to imply that the ore-bearing slates were then in the same condition as at present. On the other hand the Lower Carboniferous sandstones themselves contain in places narrow veins of specular iron, which also occurs, as well as magnetic iron, in the fissures of the Triassic trap.

On the west side of the East River of Pictou, there occur rocks precisely similar to those of the Cobequid range, of which indeed they may be regarded as an Eastern continuation, and including an iron vein which must be regarded as the equivalent of that of the Acadia Mine, which it resembles perfectly in mineral character and mode of occurrence, differing only in the greater proportionate prevalence of the specular ore.*

'In New Lairg, a few miles from Glengarry Station, the most western portion of this vein known to me, contains much Ankerite, with strings of Specular iron; and in large loose pieces there are indications also of red ore which is not visible in place. Farther to the eastward on the West Branch of the East River of Pictou, there appears a band of quartzite thirty feet thick filled with veins of Limonite; but specular ore is not found at this place. Still farther to the eastward and near the east branch of the East River the specular vein attains a very large development, shewing in some places a thickness of twenty feet of pure ore. Its course is S. 60° to 70° E. or nearly coincident with that of the containing beds; and as on the Cobequids, its attitude is nearly vertical and it appears to be thickest and richest in the rising grounds. In one very deep ravine the bed of quartzite usually associated with the ore seemed to be wanting, and the vein was represented by innumerable strings of Ankerite, forming a network in the slate. As in the Cobequid vein, masses of Magnetic ore are occasionally mixed with the Specular. To complete the resemblance, loose masses of Limonite are found in the vicinity of the vein, giving rise to the expectation that a vein or veins of this mineral may be found to be associated with the specular ore. The ores of this vein in Pictou County are nearly pure peroxide of iron, containing from 64 to 69 per cent. of metal, and can be obtained in great quantity from the outcrop of the vein where it appears on the rising grounds.

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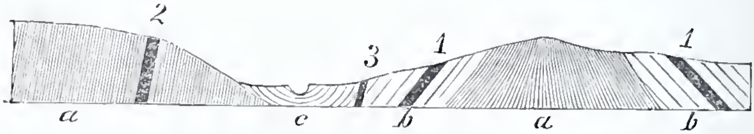
* This vein was first described by the late Mr. Hartley in the Report of the Geological Survey of Canada, 1870.



Ideal Section, showing the general relations of the Iron Ores of the East River of Pictou.

1. Great bed of Red Hematite.
2. Vein of Specular Iron.
3. Vein of Limonite.

(*a*) Older Slate and Quartzite series, with Trap, &c.
(*b*) Lower Helderberg formation and other Upper Silurian rocks.
(*c*) Lower Carboniferous of the East Branch of East River.

(2) *Limonite veins of the East River of Pictou.*

The valley of the East River of Pictou above Springville is occupied by a narrow tongue of Lower Carboniferous rocks, having at one side the slates containing the ore last mentioned, and on the other a more disturbed country already referred to as containing the great Lower Helderberg bed of Hematite. It is highly probable that the river valley follows the line of an old pre-carboniferous line of fracture, denuded and partially filled with the Lower Carboniferous beds, including large deposits of limestone and gypsum. At the line of junction of the Carboniferous and older rocks on the east side of the river, occurs the great Limonite vein of the district, forming a vein of contact of exceeding richness and value. It follows the sinuosities of the margin of the older rocks, and varies in thickness and quality in different places; being apparently richest opposite the softer slates and where these are in contact with a black manganesian limestone, which here, as in many other parts of Nova Scotia, forms one of the lowest members of the Carboniferous series. The ore is sometimes massive but more frequently in fibrous concretionary balls of large size, associated with quantities of smaller concretionary or "gravel" ore. In some places the ore of iron is associated with concretions or crystalline masses of Pyrolusite and Manganite.

Denuding agencies in the Post-pliocene period have removed portions of the vein and its wells, and have deeply covered the surface in many places with debris. Hence the outcrop of the vein was originally marked by a line of masses of the ore too heavy to be removed by water. From the analogy of the other veins to be mentioned in the sequel, I was led to believe that the source of these masses would be found in the Lower Carboniferous rocks, and so stated the matter in the first edition of Acadian Geology (1855). Subsequently, however, the vein having been exposed in situ, and one wall proving to consist of metamorphic slate, it was described by Dr. Honeyman and by Mr. Hartley of the Geological Survey as a vein in the Silurian rocks. Still more recently exploratory works conducted by Mr. G. M. Dawson, with the aid of Mr. D. Fraser, have clearly proved that the vein follows the junction of the two formations. The ore of this vein is of the finest quality, affording from 62 to 65 per cent. of metallic iron. The more productive portions of this vein, as well as of the specular vein in its vicinity, are in the hands of the parties already referred to, in connection with the Hematite bed.

(3) *Limonite of Shubenacadie, Old Barns and Brookfield.*

At the mouth of the Shubenacadie River, the lowest Carboniferous bed seen is a dark-coloured laminated limestone, in all probability the equivalent of the Manganesian limestone already referred to, as well as of the Manganiferous limestone of Walton, the Plumbiferous limestone of the Stewiacke, and the lower black limestone of Plaister Cove, Cape Breton.* This limestone and the sandstones and marls overlying it, are traversed by large fissure veins, holding a confused aggregation of iron ores and other minerals, as Limonite, Hematite, Gothite, Sulphate of Barium, Calcite, &c., some of which appear sufficiently large and rich for profitable exploration. In the same formations, further to the eastward, at Old Barns, similar veins are found to be largely developed, and at Brookfield, fifty miles east of the Shubenacadie, and apparently near the junction of the Lower Carboniferous with older rocks, large surface masses of Limonite appear to indicate an extensive deposit of similar nature, but which has not, I believe, been yet so far opened up as to establish its practical importance.

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* See Acadian Geology.

(4) *Iron Veins of the Triassic Trap.*

Veins of Magnetite and Specular Iron occur in several localities in the great beds of trap associated with the Triassic red sandstones of the Bay of Fundy, but so far as known these ores are insignificant in quantity.

It will be observed from the above notes, that while the iron vein of the Cobequid hills is at no great distance from the coalfield of Cumberland, with which it has now railway connection, the still larger and more important deposits of Pictou are very near to the extensive collieries of that district, and to railway and water communication, so that every facility appears to exist for their profitable exploration, and it may be anticipated that they will soon be rendered available for the supply of iron of superior quality, more especially to meet the large and increasing demand of the Dominion of Canada.

[From the American Journal of Science and Arts, Vol. XVII, March. 1879.]

MÖBIUS ON EOZOON CANADENSE.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

By J. W. DAWSON, LL.D., F.R.S.

[From the American Journal of Science and Arts, Vol. XVII, March, 1879.]

Möbius on Eozoon Canadense;* by J. W. Dawson, LL.D., F.R.S.

Eozoon Canadense has, since the first announcement of its discovery by Logan in 1859, attracted much attention, and has been very thoroughly investigated and discussed, and at present its organic character is generally admitted. Still its claims are ever and anon disputed, and as fast as one opponent is disposed of, another appears. This is in great part due to the fact that so few scientific men are in a position fully to appreciate the evidence respecting it. Geologists and mineralogists look upon it with suspicion, partly on account of the great age and crystalline structure of the rocks in which it occurs, partly because it is associated with the protean and disputed mineral Serpentine, which some regard as eruptive, some as metamorphic, some as pseudomorphic, while few have had enough experience to enable them to understand the difference between those serpentines which occur in limestones, and in such relations as to prove their contemporaneous deposition, and those which may have resulted from the hydration of olivine or similar changes. Only a few also have learned that *Eozoon* is only sometimes associated with serpentine, but that it occurs also mineralized with loganite, pyroxene, dolomite, or even earthy limestone, though the serpentinous specimens have attracted the most attention, owing to their beauty and abundance in certain localities. The biologists on the other hand, even those who are somewhat familiar wtth foraminiferal organisms, are little acquainted with the appearance of these when mineralized with silicates, traversed with minute mineral veins, faulted, crushed and partly defaced, as is the case with most specimens of *Eozoon*. Nor are they willing to admit the possibility that these ancient organisms may have presented a much more generalized and less definite structure than their modern successors. Worse, perhaps, than all these, is the circumstance that dealers and injudicious amateurs have intervened, and have circulated specimens of *Eozoon*, in which the structure is too imperfectly preserved to admit of its recognition, or even mere fragments of serpentinous limestone, without any structure whatever. I have seen in the collections of dealers and even in public museums, specimens labelled "*Eozoon Canadense*" which have as little claim to that designation as a chip of limestone has to be called a coral or a crinoid.

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* Der Bau des Eozoon Canadense, von Karl Möbius, Professor der Zoologie in Kiel. Palæontographica, Band xxv.

The memoir of Professor Möbius affords illustrations of some of these difficulties in the study of *Eozoon*. Professor Möbius is a zoologist, a good microscopist, fairly acquainted with modern foraminifera, and a conscientious observer; but he has had no means of knowing the geological relations and mode of occurrence of *Eozoon*, and he has had access merely to a limited number of specimens mineralized with serpentine. These he has elaborately studied, and has made careful drawings of portions of their structures, and has described these with some degree of accuracy; and his memoir has been profusely illustrated with figures on a large scale. This, and the fact of the memoir appearing where it does, convey the impression of an exhaustive study of the subject, and since the conclusion is adverse to the organic character of *Eozoon*, this paper may be expected, in the opinion of many not fully acquainted with the evidence, to be regarded as a final decision against its animal nature. Yet, however commendable the researches of Möbius may be, when viewed as the studies of a naturalist desirous of satisfying himself on the evidence of the material he may have at command, they furnish only another illustration of partial and imperfect investigation, quite unreliable as a verdict on the questions in hand. The following considerations will serve to indicate the weak points of the memoir.

1. A number of errors and omissions arise from want of study of the fossil *in situ*, and from want of acquaintance with

its various states of preservation. Trivial errors of this kind are his referring to my photograph in Plate III, of the "Dawn of Life," as if it were natural size, and his stating that the larger specimens have fifty laminæ, whereas they often have more than an hundred. More important is his failing to appreciate aright the occurrence of *Eozoon* in certain layers of regularly bedded limestones, the rounded or club-shaped forms of the more perfect specimens, the manner in which the layers become confluent at the edges of the forms, as described by Sir W. E. Logan and myself, or the amount of crushing and fracture which most of the specimens exhibit. Thus he fails to convey any adequate idea of the Stromatoporoid forms and mode of occurrence of the organism, or indeed of its general character and probable mode of growth. Farther he treats it from the first as a mere laminated aggregate of calcite and serpentine, without reference to its occurrence in any other state, and also without reference to the fragmental limestones in part made up of its remains. He objects strongly to the want of definiteness of form and distribution in the chambers and connecting passages, without making allowance for defects of preservation, or mentioning the similar want of defined form in some *Stromatoporæ*. He admits, however, that the modern *Carpenteria* and its allies are in some respects equally indefinite. He farther objects to the impossibility of detecting regular primary chambers like those in modern foraminifera, but seems not to be aware that, as I have recently shown, some *Stromatoporæ* originate in a vesicular, irregular mass of cells, and that in *Loftusia*, both the Eocene *L. Persica*, and the Carboniferous *L. Columbiana*, the primary chamber is represented by a merely cancellated nucleus.*

2. With reference to the finely tubulated proper wall of Eozoon, he has fallen into an error scarcely excusable in an observer of his experience, except on the plea of insufficient access to specimens. He confounds the proper wall with the chrysotile veins traversing many of the specimens, and obviously more recent than the bodies whose fissures they fill. That he does so is apparent from his stating that the proper-wall structure sometimes crosses the bands of serpentine and calcite, and also that it presents a series of parallel four-sided prisms, whereas, when at all perfectly preserved, it shows a series of cylindrical threads penetrating a calcite wall. That some of his specimens have contained the proper wall fairly preserved is obvious from his own figures, in which it is possible to recognize both this structure and chrysotile veins, though confounded by him under the same designation. He objects, somewhat naïvely, that many of the chambers fail to exhibit

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* See Journal of London Geol. Soc., January, 1878.

this nummuline wall, and that it sometimes presents a ragged appearance or is altogether opaque. In point of fact it can appear distinctly, either in decalcified specimens or in slices, only when the minute tubes are filled with some substance optically distinguishable from calcite, or not acted on by dilute acid. When the proper wall is merely calcareous (and I have specimens showing that it is often in this state, and without any serpentine in its pores), its structure is ordinarily invisible, and it is the same when the calcareous skeleton has from any cause lost its transparency or has been replaced by some other mineral substance. Even in thickish slices, the tubes, though filled with serpentine, may be so piled on one another as to be indistinct. All this may be seen in Tertiary *Nummulites.* When wholly calcareous their tubulation is often quite invisible, and when imperfectly injected with glauconite or other silicates, they often present a very irregular appearance. If Professor Möbius will study the Nummulites injected with glauconite from Kempten,* Bavaria, in addition to the casts of *Polystomella* from the Ægean to which he refers, he will be better able to appreciate these points. It may be worth repeating here that, in examining the original specimens of Eozoon, I did not recognize the proper wall. I did not doubt that it must have existed in some form, since I could easily detect the canals in the supplemental skeleton; but I did not wonder at its non-appearance, knowing the chances against its preservation in a recognizable form. Its discovery was due to the subsequent investigations of Dr. Carpenter.†

3. To the canal system, Professor Möbius does more justice, and admits its great resemblance to the forms of this structure in modern *Foraminifera.* This indeed appears from his own figures, as will be seen from the fac-simile tracings reproduced here, figs. 1, 2, 3 and 4, which well show how wonderfully this structure has been preserved, and how nearly it resembles the similar parts of modern *Foraminifera.* He thinks, however, that these round and regularly branching forms are rather exceptional, which is a mistake; though it is true that the sections of the larger canals are often somewhat flattened, and that they become flat where they branch. They are also sometimes altered by the vicinity of veinlets or fractures, or by minute mineral segregations in the surrounding calcite, accidents to which all similar structures in fossils are liable. Another

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*I am indebted to Dr. Otto Hahn for specimens of these most interesting fossils.

† It may deserve mention here that the Carboniferous *Fusulina* very rarely shows its tubulated wall, and that Dr. Carpenter had maintained its Nummuline affinities before he obtained specimens showing this particular structure. Structures so delicate as these are indeed only preserved exceptionally in fossil specimens.

objection, not original with him, is derived from their unequal dimensions. It is true that they are very unequal in size, but there is some definiteness about this. They are larger in the thicker and earlier formed layers, smaller or even wanting in the thinner and more superficial. In some slices the thicker trunks only are preserved, the slender branches having been filled with dolomite or calcite. It is difficult, also, to obtain, in any slice or any surface, the whole of a group of canals.* Farther, as I have shown, the thick canals sometimes give off groups of very minute tubes from their sides, so that the coarser and finer canals appear intermixed. These appearances are by no means at variance with what we know in other organic structures. Another objection is taken to the direction of the canals, as not being transverse to the laminæ but oblique. This, however, may be dismissed, since Möbius has of course to admit that it is not unusual in modern *Foraminifera*. It may be added that some of the appearances which puzzled Möbius, and which are represented in his figures, evidently arise from fractures displacing parts of groups of canals, and from the apparently sudden truncation of these at points where the serpentine filling gives place to calcite. It would also have been well if he had studied the canal systems of those *Stromatoporæ* which have a secondary or supplemental skeleton, as *Cœnostroma* and *Caunopora*. In illustration of this I give in fig. 5 a group of these canals from a recent paper of my own.†

4. A fatal defect in the mode of treatment pursued by Möbius is that he regards each of the structures separately, and does not sufficiently consider their cumulative force when taken together. In this aspect, the case of *Eozoon* may be presented thus: (1.) It occurs in certain layers of widely distributed limestones, evidently of aqueous origin, and on other grounds presumably organic. (2.) Its general form, lamination and chambers, resemble those of the Silurian *Stromatopora* and its allies, and of such modern sessile foraminifera as *Carpenteria* and *Polytrema*. (3.) It shows under the microscope a tubulated proper wall similar to that of the Nummulites, though of even finer texture. (4.) It shows also in the thicker layers a secondary or supplemental skeleton with canals. (5.) These forms appear more or less perfectly in specimens mineralized with very different substances. (6.) The structures of *Eozoon* are of such generalized character as might be expected in a very early Protozoan. (7.) It has been found in various parts of the world under very similar forms, and in beds approximately of the same geological horizon. (8.) It may be

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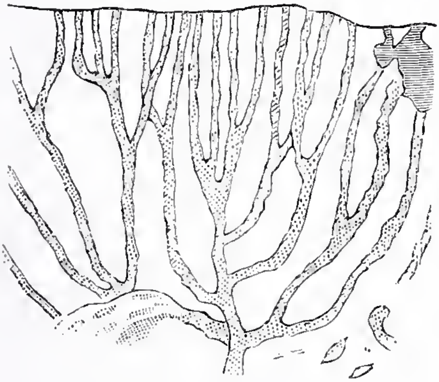
* I have succeeded best in this by etching the surface of broken specimens.

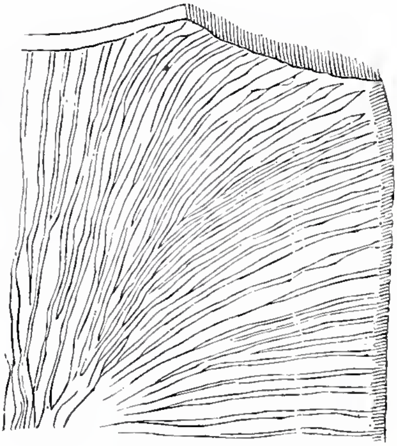
† Journal of London Geological Society, January, 1878.

1.



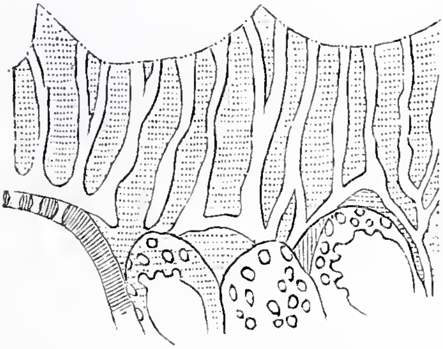
Canals of *Eozoon* (after Möbius).

2.



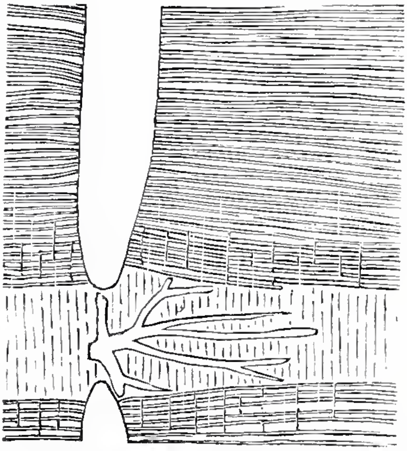
Finer canals of *Eozoon* (after Möbius).

3.



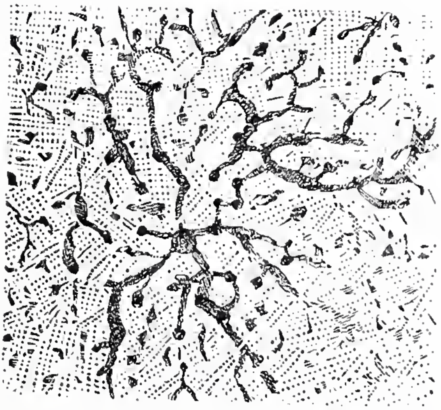
Canals of modern *Calcarina* (after Möbius).

4.



Canals and Tubule of Tertiary *Nummulina* (after Möbius).

5.



Canals of *Cœnostema*—Upper Silurian—(original).

added, though perhaps not as an argument, that the discovery of *Eozoon* affords a rational mode of explaining the immense development of limestones in the Laurentian age; and on the other hand that the various attempts which have been made to account for the structures of *Eozoon* on other hypotheses than that of organic origin have not been satisfactory to chemists or mineralogists, as Dr. Hunt has very well shown.

Professor Möbius, in summing up the evidence, hints that Dr. Carpenter and myself have leaned to a subjective treatment of *Eozoon*, representing its structure in a somewhat idealized manner. In answer to this it is necessary only to say that we have given photographs, nature-prints and camera tracings of specimens actually in our possession. We have not thought it desirable to figure the most imperfect or badly preserved specimens, though we have taken pains to explain the nature and causes of such defects. Of course, when attempts at restoration have been made, these must be taken as to some extent conjectural; but so far as these have been attempted they have consisted merely in the effort to eliminate the accidental conditions of fossilized bodies, and to present the organism in its original perfection. Such restorations are not to be taken as evidence, but only as illustrations to enable the facts to be more easily understood. It is to be observed, however, that in the study of such fossils as *Eozoon*, the observer must expect that only a small proportion of his specimens will show the structures with any approach to perfection, and that comparison of many specimens prepared in different ways may be necessary in order to understand any particular feature. A single figure or a short description may thus represent the results of days spent in the field in collecting, of careful examination and selection of the specimens, of the cutting of many slices in different directions, and of much study of these with different powers and modes of illumination. My own collection contains hundreds of preparations of *Eozoon*, each of which represents perhaps hours of labor and study, and each of which throws some light more or less important on some feature of structure. The results of labor of this kind are unfortunately very liable to be regarded as subjective rather than objective by those who arrive at conclusions in easier ways.

Taken with the above cautions and explanations, the memoir of Professor Möbius may be regarded as an interesting and useful illustration of the structures of Eozoon, though from a point of view somewhat too limited to be wholly satisfactory.

[From the American Journal of Science, Vol. XX, November, 1880.]

REVISION OF THE LAND SNAILS OF THE PALEOZOIC ERA, WITH DESCRIPTIONS OF NEW SPECIES.

By J. [illegible] Daws

[From the American Journal of Science, Vol. XX, November

REVISION OF T LAND SNA PALEOZOIC ERA, WITH DES TIONS OF NEW SPECIES.

By J. W. Dawson.

The Gasteropods as a class occur as early as the Upper Cambrian, but all the earlier known types are marine. That portion of the group distinguished by the possession of air sacs instead of gills (Pulmonifera) has not hitherto been found in any formation other than the Carboniferous, and only four Carboniferous species have been described. In the present paper

I propose to state some additional facts respecting the species already known, to discuss their affinities, and to describe two additional species, making six in all from the Paleozoic rocks, including one from the Erian or Devonian. For reasons to be mentioned in the sequel, I do not admit the genus *Palæorbis* founded, by some German naturalists, on fossils which I believe to be tubes of Annelids.

It may be useful to premise that of the two leading subdivisions of the group of Pulmonifera, the Operculate and Inoperculate, the first has been traced no farther back than the Eocene. The second, or Inoperculate division, includes some genera that are aquatic and some that are terrestrial. Of the aquatic genera no representatives are known in formations older than the Wealden and Purbeck, and these only in Europe. The terrestrial group or the family of the *Helicidæ*, which, singularly enough, is that which diverges farthest from the ordinary gill-bearing Gasteropods, is the one which has been traced farthest back, and includes the Paleozoic species. It is further remarkable that a very great gap exists in the geological history of this family. No species are known between the Carboniferous and the early Tertiary, though in the intervening formations there are many fresh-water and estuarine deposits in which such remains might be expected to occur.
is perhaps no reason to doubt the continuance of the
hrough this long portion of geological time, though
hat during the interval the family did not
umber of species, more especially as
mination in the modern
ated many and large species,
nearly s of our continents.
ence of the ic Pulmonifera in the
they have d is characteristic.
n species, *Pupa* was found by Sir
nd the writer, in the filling the once
a Sigillaria at the South s in Nova Scotia,
additional specimens have quently been ob-
n similar repositories in the same locality, where they
ciated with bones of Batrachians and remains of Milli-
. Other specimens, and also the species *Zonites priscus*,
e been found in a thin, shaly layer, containing debris of
ants and crusts of Cyprids, and which was probably deposited at the outlet of a small stream flowing through the coal-formation forest. The two species found in Illinois occur, according to Bradley, in an underclay or fossil soil which may have been the bed of a pond or estuary, and subsequently became a forest sub-soil. The Erian species occurs in shales charged with remains of land plants, and which must consequently have

received abundant drainage from neighboring land. It is only in such deposits that remains of true land-snails can be expected to occur; though, had fresh-water or brackish water Pulmonates abounded in the Carboniferous age, their remains should have occurred in those bituminous and calcareo-bituminous shales which contain such vast quantities of debris of Cyprids, Lamellibranchs and fishes of the period, mixed with fossil plants.

With reference to their affinities, the Paleozoic land snails present no very remarkable peculiarity except their close resemblance to some modern forms. Of the known species, four belong to the genus *Pupa* in its wider sense, and are very near to sub-generic types still represented on the American continent and its islands. One is a small helicoid shell not separable from the modern genus *Zonites*, and the remaining one, though it has been placed in a new genus, is very near to some small American snails of the present day (*Stenotrema*, etc.) All the species are of small size, though not smaller than some modern shells of the same types.

I shall now proceed to give the characters and descriptions of the several species, adding to the account of those previously known, such new facts as have occurred in my more recent explorations and examinations. I should state here that many of the new facts detailed have been obtained in the course of excavations for the extraction of erect trees holding land animals, undertaken with the aid of a grant from the Government fund for aiding original researches, at the disposal of the Royal Society of London, and carried on within the past three years.

1. *Pupa vetusta* Dawson. (Figs. 1 to 4, and 14, *a*, *b*.)

[Sir C. Lyell and Dr. Dawson on Remains of Reptiles and a Land shell from the South Joggins in Nova Scotia, Journal of Geological Society of London, vol. ix, 1832 (figured but not named). Dawson's Acadian Geology, 1855, p. 160. Dawson's Air-breathers of the Coal Period, 1863. Acadian Geology, 2d and 3d editions, p. 384, 1868 and 1879.]

Description.—Shell cylindrical, somewhat abruptly conical at the apex, in some specimens tending to diminish in diameter in the later turns or whorls of the shell. Whorls nine in adult shells, slightly convex, in width equal to half the diameter of the shell. Suture impressed. Aperture evenly rounded, not continuous above, rather longer than broad, destitute of teeth; peristome slightly reflected and smooth. Surface shining, marked with longitudinal smooth ridges, separated by spaces a little wider than the ridges; spaces about $\frac{1}{500}$th inch in width. Shell calcareous, thin, prismatic in structure. Young specimens abruptly conical and helicoid in form. Nucleus round, smooth, the first turn below the nucleus marked with rows of little pits which gradually pass into the continuous striæ. The last whorl of the adult presents irregular lines of growth, instead of the regular microscopic ribs of the middle turns. Mature ovum membranous, or so slightly calcareous that it can be compressed without breaking: the embryo shell sometimes visible within. Length of adult shell rather less than 1 centimeter, breadth in middle 4 millimeters.

Variety tenuistriata.—Along with the ordinary form there are others of similar size and general structure, but with the apex less obtuse and a somewhat greater tendency to diminish in diameter in the later whorls. They have also the microscopic ridges in the shell about half as far apart as those of the ordinary form. This form I was at first disposed to regard as specifically distinct, but there seems to be a gradual transition from one to the other, and the two forms seem to accompany each other throughout the entire range of the species.

State of preservation.—The shells are usually entire, but often somewhat flattened, and cracked or distorted in the process. Many fragments of shells, however, occur with the entire specimens, and some of these have a whitened or bleached appearance like that of modern land shells after having been exposed to the weather. In one layer I found impressions of several flattened shells, the substance of the shell having been altogether removed. Ordinarily the shell remains in such a state as to show its structure, and the more perfect specimens found in the erect trees have a grayish brown color, like that of some modern Pupæ.

The habitat of this species was in forests of the Coal-formation period, composed of *Sigillaria*, *Calamites*, *Lepidophloios* and *Ferns*. The only known locality is the South Joggins, Nova Scotia. At this place the shells have been obtained in considerable numbers, though perfect specimens which can be disengaged from the matrix, are comparatively few. They have been found in erect *Sigillariæ* and also in a bed of shale. The lowest and highest beds in which they occur are separated by 2,000 feet of vertical thickness of strata including no less than thirty-five beds of coal and many underclays supporting erect trees, so that the species must have inhabited this locality for a very long time and must have survived many physical vicissitudes.

The first specimen, which was also the first known Paleozoic land shell, was found by Sir Charles Lyell and the writer in 1851, in breaking up the contents of an erect tree holding reptilian bones. The specimens obtained from this tree having been taken by Sir Charles to Cambridge and submitted to the late Prof. Jeffries Wyman, the shell in question was recognized by him and the late Dr. Gould, of Boston, as a land shell. It

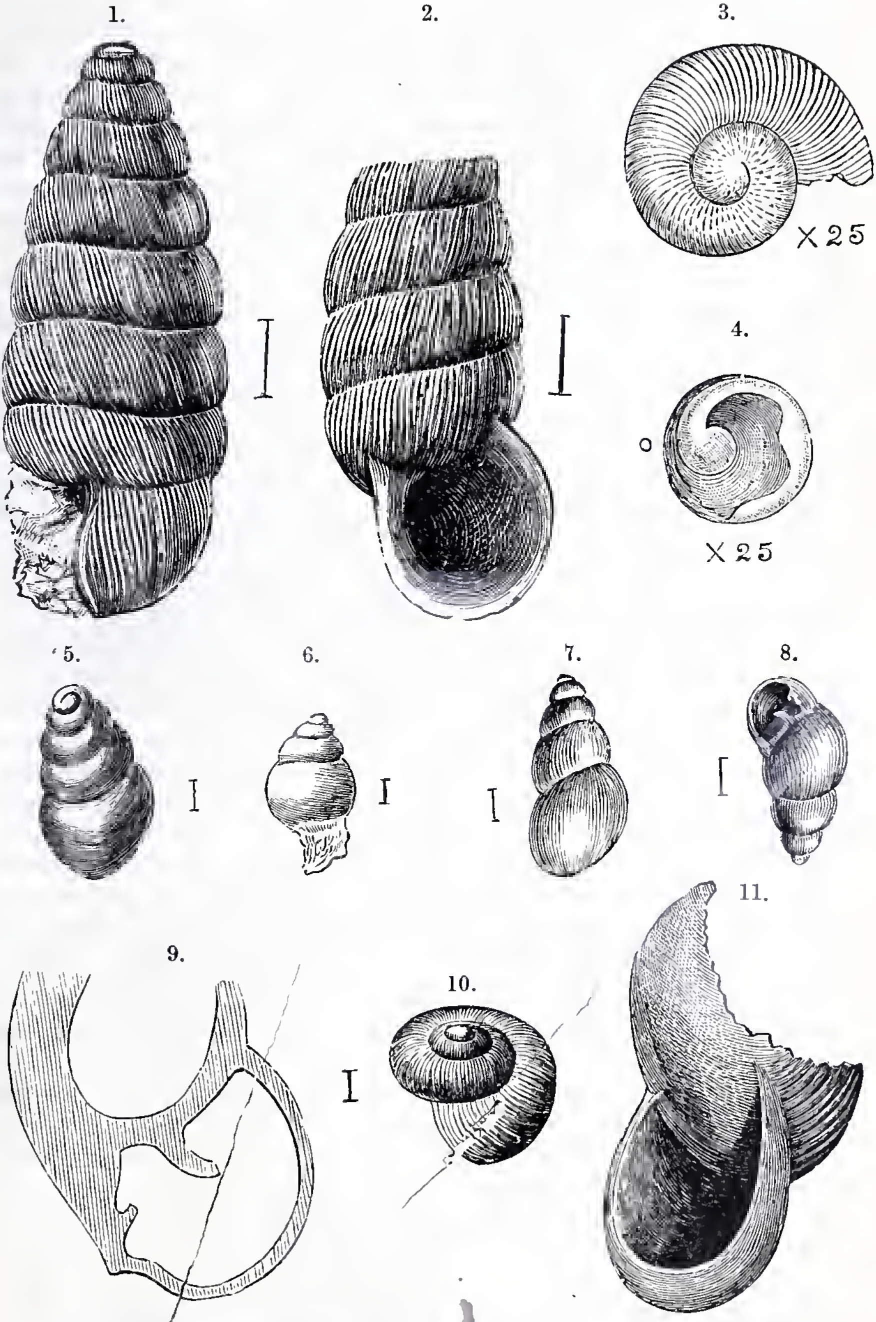


Fig. 1, *Pupa vetusta*, magnified 8 times li[illegible]eally; 2, same, showing the aperture, ×8; 3, same, nuclear whorl, ×25; 4, sam[illegible]mature egg and embryo shell, ×25. 5, 6, *Pupa Bigsbii*, ×8. 7, *Pupa Vermi*[illegible]*ensis*, ×8; 8, same, showing aperture ×8, the small tooth on the colun[illegible] somewhat exaggerated; 9, same, section of aperture, showing tooth ×16[illegible]0, *Zonites priscus*, ×8; 11, same, crushed specimen, showing aperture ×20 was subsequently examined by M. Deshayes and Mr. Gwyn Jeffries, who concurred in this determination; and its microscopic structure was described by the late Prof. Quekett, of London, as similar to that of modern land shells. The single specimen obtained on this occasion was somewhat crushed and did not show the aperture. Hence the hesitation as to its nature, and the delay in naming it, though it was figured and described in the paper above cited in 1852. Better specimens showing the aperture were afterward obtained by the writer, and it was named and described by him in his "Air-breathers of the Coal Period," in 1863. Prof. Owen, in his 'Palæontology,' subsequently proposed the generic name *Dendropupa.* This I have hesitated to accept, as expressing a generic distinction not warranted by the facts; but should the shell be considered to require a generic or sub-generic distinction, Owen's name should be adopted for it. There seems, however, nothing to prevent it from being placed in one of the modern sub-genera of simple-lipped Pupæ. With regard to the form of its aperture, I may explain that some currency has been given to an incorrect representation of it, through an unfortunate accident. In the case of delicate shells like this, imbedded in a hard matrix, it is of course difficult to work out the aperture perfectly; and in my published figure in the "Air-breathers," I had to restore somewhat the broken specimens in my possession. This restoration, specimens subsequently found have shown to be very exact. Nevertheless it was criticised by some English conchologists, and when Sir Charles Lyell was about to publish his Student's Manual, he asked me to give him one of my best specimens to be figured. This I sent with micro-photographs of others. It seems, however, that the artist or engraver mistook the form of the aperture and gave it an entirely unnatural appearance in the Student's Manual. That now given is taken from a photograph of the most perfect and least compressd specimen in my possession.

As already stated, this shell seems closely allied to some modern Pupæ. Perhaps the modern species which approaches most nearly to it in form, markings and size, is *Macrocheilus Gossei* from the West Indies, specimens of which were sent to me some years ago by Mr. Bland, of New York, with the remark that they must be very near to my Carboniferous species. Such edentulous species as *Pupa* (*Leucochila*) *fallax* of Eastern America very closely resemble it; and it was regarded by the late Dr. Carpenter as probably a near ally of those species which are placed by some European conchologists in the genus *Pupilla.*

The lowest bed in which *Pupa vetusta* occurs belongs to group VIII of Division 4 of my section of the South Joggins, and is between Coal 37 and Coal 38 of Logan's section, being about 42 feet below Coal 37. The next horizon, and that in which the shell was first discovered, is 1217 feet of vertical thickness higher, in group XV of Division 4 of my section. The shells occur here in erect *Sigillariæ*, standing on Coal 15 of Logan's section. The third horizon is in group XXVI of Division 4, about 800 feet higher than the last. Here also the shells occurred in an erect *Sigillaria.*

In the lowest of these three horizons, the shells are found, as already stated, in a thin bed of concretionary clay of dark gray color, though associated with reddish beds. It contains *Zonites priscus* as well, though this is very rare, and there are a few valves of *Cythere* and shells of *Naiadites* as well as carbonaceous fragments, fronds of ferns, *Trigonocarpa*, etc. The *Pupæ* are mostly adult, but many very young shells also occur, as well as fragments of broken shells. The bed is evidently a layer of mud deposited in a pond or creek, or at the mouth of a small stream. In modern swamps, multitudes of fresh-water shells occur in such places, and it is remarkable that in this case the only gasteropods are land shells, and these very plentiful, though only in one bed about an inch in thickness. This would seem to imply an absence of fresh-water Pulmonifera. In the erect *Sigillariæ* of group XV, the shells occur either in a sandy matrix, more or less darkened with vegetable matter, or in a carbonaceous mass composed mainly of vegetable debris. Except when crushed or flattened, the shells in these repositories are usually filled with brownish calcite. From this I infer that most of them were alive when imbedded, or at least that they contained the bodies of the animals; and it is not improbable that they sheltered themselves in the hollow trees, as is the habit of many similar animals in modern forests. Their residence in these trees as well as the characters of their embryology are illustrated by the occurrence of their mature ova. They may also have formed part of the food of the reptilian animals whose remains occur with them. In illustration of this I have elsewhere stated that I have found as many as eleven unbroken shells of *Physa heterostropha* in the stomach of a modern *Menobranchus.* I think it certain, however, that both the shells and the reptiles occurring in these trees must have been strictly terrestrial in their habits, as they could not have found admission to the erect trees unless the ground had been sufficiently dry to allow several feet of the imbedded hollow trunks to be free from water. In the highest of the three horizons the shells occurred in an erect tree, but without any other fossils, and they had apparently been washed in along with a grayish mud.*

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* The discovery of the shells in this tree was made by Albert I. Hill, C.E.

2. *Pupa Bigsbii* s. n. (Figs. 5 and 6.)

Description.—Shell half the size of *Pupa vetusta*, or between three and four millimeters in length and one and five-tenths millimeters in breadth. Form, long conical. Body whorl about one-third of the entire length, giving the shell a somewhat bulimoid form. Whorls five in the largest specimens found, tumid, suture much impressed. Surface smooth. Aperture apparently oval in form, but not perfectly known, as the body whorl is crushed in all the specimens.

A few specimens, none of them quite perfect, were found in the erect trees of group XV at the Joggins, along with *Pupa vetusta.* They differ from that species in smaller size, different form and absence of sculpture. The specimens do not show whether the aperture was toothed or simple, but it was probably the latter, as the lip is evidently very thin and delicate. From its form it is probable that it belongs to a different subgenus from *P. vetusta.* It is very much more rare than that species in the erect trees, and has not been found elsewhere.

I dedicate it to my venerable and dear friend Dr. Bigsby, F.R.S., of London, a pioneer in American geology, and still an indefatigable worker in the science.

3. *Pupa Vermilionensis* Bradley. (Figs. 8 and 9, and 14*c*.)

[Bradley in Report of Geological Survey of Illinois, vol. iv, p. 254. Id. in Am. Journ. Sci., III, vol. iv, p. 87.]

*Description.**—Shell spindle-shaped, tapering to an obtuse apex, covered with microscopic ridges (25 to 30 in a millimeter) parallel to the lines of growth. Aperture oblique, oval. Outer lip thin, slightly reflexed. Columella lip reflexed, thickened; furnished with a single central curved tooth, projecting nearly half way across the aperture. Junction of columella and outer lip somewhat angular and dentiform. In old individuals the columella tooth is often continuous through an entire turn or farther. It is not seen on shells having less than three turns. The last turn forms nearly half the length of the shell. Whorls rounded. Suture impressed. Surface glossy. Color black or gray. Length three and six-tenths millimeters. Width two millimeters. Some individuals are smooth or destitute of the fine microscopic ridges, but whether this is a natural peculiarity or a result of injury to the outer surface, is not certain.

As compared with *Pupa vetusta* this shell is less than half the size, of a less cylindrical form, its whorls more rounded, and its body whorl much larger in proportion. Its sculpture is much finer. The conspicuous tooth in the aperture is of course also a strong mark of distinction. The shell is thin, and from its black color and failure to show structure under the microscope, I infer that it must have been of a horny or corneous texture, with little calcareous matter. The matrix is light colored and concretionary, and somewhat hard and calcareous.

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* Slightly modified from Bradley.

As compared with modern American species, *P. Vermilionensis* is very near to several of the smaller forms with teeth in the aperture. In its form and aperture it approaches closely to *P.* (*Leucochila*) *corticaria* of Say, or to the immature shell of *P. rupicola.* It has also some resemblance to the western species *P. hordeacea* Gabb, from Arizona.

This shell was discovered by the late Mr. F. H. Bradley in 1869, in concretionary limestone accompanying the underclay of Coal No. 6, Wabash Valley Section, at Pelly's Fort, Vermilion River, Illinois. In the first notice, which appeared in the Report of the Geological Survey of Illinois, it was referred to *Pupa vetusta*, but was subsequently described by Mr. Bradley in the American Journal of Science, under the name above cited.

I am indebted for specimens of this shell to Mr. John Collett, of the Geological Survey of Indiana, and also to Mr. W. Gurley, of Danville, Illinois.

4. *Zonites* (*Conulus*) *priscus* Carpenter. (Figs. 10 and 11, and 14*d.*)

[Quarterly Journal of Geological Society of London, Nov. 1867. Acadian Geology, 2d edition, 1868, p. 385.]

*Description.**—Shell small, helicoid. Length two and five-tenths millimeters, width two and eight-tenths millimeters. Spire little elevated. Nucleus small. Whorls four, somewhat flattened, with the suture little impressed. Base somewhat excavated with large umbilicus. Aperture oblique, suboval, somewhat regularly rounded. Lip simple. Surface marked with uneven striæ and somewhat more conspicuous ridges of growth. Angle of divergence about 130°. Shell thin and probably horny.

This little shell was discovered in 1866, in the bed already referred to as the lowest of those at the South Joggins in which *Pupa vetusta* has been found. Shortly after I had discovered this bed, being impressed with the probability that it might hold other remains of land animals beside the *Pupa*, I had some excavations made in it, and a considerable quantity of material taken out. I found, however, that the thin layer containing the land shells was not continuous but in limited patches, and was rewarded only by the discovery of a few

* Slightly modified from Carpenter.

specimens of *Zonites priscus* and a small and not determinable fragment of bone, in addition to specimens of *Pupa vetusta.*

The specimens found at this time were submitted to the late Dr. P. P. Carpenter, by whom the species was named and described. One or two crushed specimens have been subsequently found in the erect trees holding *Pupa vetusta* in group XV, but the species is extremely rare in comparison. This may however have depended on some difference in habitat or mode of life, rendering it less likely to be imbedded in the deposits in process of formation. It is also to be observed that the shell is much more delicate than that of *Pupa vetusta*, and therefore less likely to be preserved.

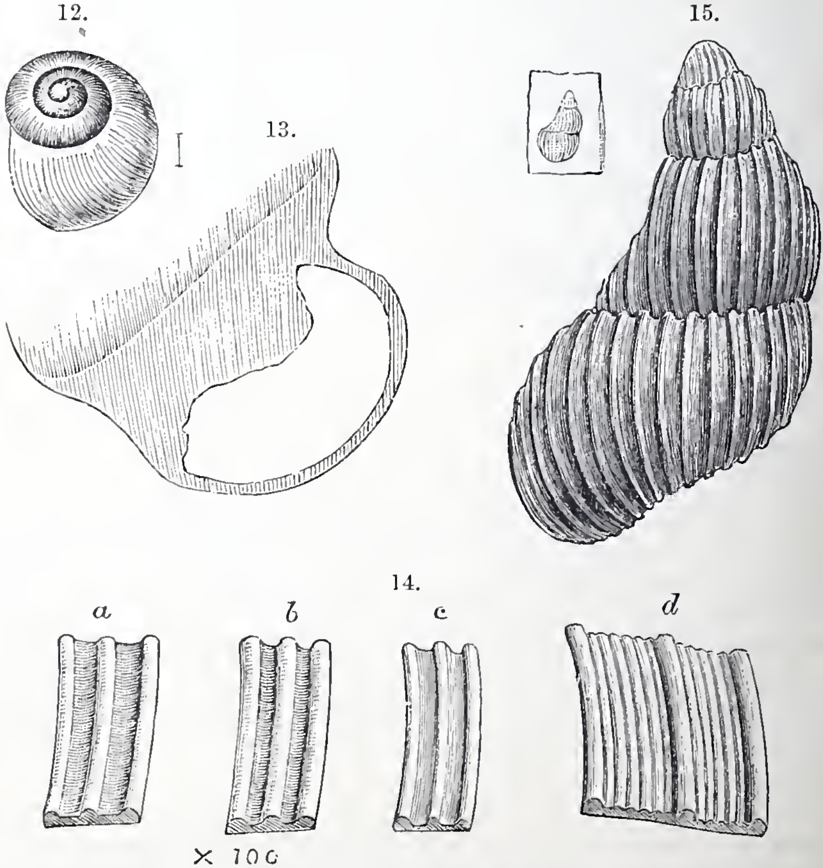

Fig. 12, *Dawsonella Meeki*, ×8; 13, same, section of aperture, ×16; the outer edge of the lamella is imperfect. 14, Markings of surface ×100: (*a*) *Pupa vetusta*; (*b*) *Pupa vetusta* var. *tenuistriata*; (*c*) *Pupa Vermilionensis*; (*d*) *Zonites priscus*; 15, *Strophites grandæva*, natural size and magnified 8 diameters.

With regard to its affinities, it was compared by Dr. Carpenter with the African species *Paryphanta Caffra* Fer., "on an extremely small scale." Dr. Carpenter also compared it with *Hygromia*, and stated that it might well be ranked under *Pseu-*

dohyalina of Morse, with the living species *minuscula* and *exigua*. He thought it best, however, to place it in the subgenus *Conulus* of the genus *Zonites*, as defined by Messrs. Adams. With regard to the subgeneric name, Dr. Carpenter explained that the subgenus *Conulus* of Fitz, 1833, appears to be synonymous with *Trochiscus* Held, 1837 (non Sby.); also with *Petasia* Beck, 1837; and with *Perforatella* Schlütt.; and according to Adams is a subgenus of *Zonites* Montf. (non Leach, Gray). Those who do not care to enter into these subgeneric distinctions, may designate the species as a *Zonites*, or even, speaking loosely, as a *Helix*. There seems nothing in its characters to separate it, more than specifically, from many of our smaller helicoid snails with thin shells and simple aperture.

5. *Dawsonella Meeki* Bradley. (Figs. 12 and 13.)

[Report of Geological Survey of Illinois, vol. iv, p. 254. Am. Journ. of Sci., III, vol. iv, p. 88. Ibid, vol. vii, p. 157.]

*Description.**—Shell broad, depressed, helicoid. Spire obtuse, consisting of three to three and one-half turns. Length three and two-tenths millimeters, width four millimeters. Surface smooth, but with fine microscopic lines of growth, about fifteen in a millimeter. Aperture oblique, oval, greatly contracted by a broad lamellar expansion of the columella, extending more than half way across, even in small individuals. Outer lip thickened, slightly reflexed. Suture little impressed, imperforate, but last turn slightly excavated in the umbilical region. The shell is usually black in color, and under the microscope shows no distinct structure, from which it may be inferred that it was corneous in texture. It is thicker than the shell of *Zonites priscus*.

This species is found along with *Pupa Vermilionensis*, and was discovered by Bradley, who was, however, at first disposed to refer it to genus *Anomphalus* of Meek; but subsequently, and with good reason, regarded it as distinct and as a land shell. In size and general form it resembles *Zonites priscus*, though expanding less rapidly and with rounder whorls; but it is at once distinguished by its want of the somewhat coarse sculpture of that species, and by the plate which partially covers its aperture. Its nearest modern allies in eastern America would seem to be such shells as *Helix* (*Triodopsis*) *palliata*, and *H.* (*Stenotrema*) *monodon*.

For specimens of this shell I am indebted to the persons above named as having furnished specimens of *Pupa Vermilionensis*.

6. *Strophites grandæva*, s. n. (Fig. 15.)

Description.—Shell cylindrical, with obtuse apex. Whorls four or more. Surface covered with sharp vertical ridges, separated by spaces three times as wide. The body whorl about 4 millimeters in diameter, with about thirteen vertical ridges visible on one side. Length of a specimen probably not quite perfect, about 8 millimeters. The shell, which has disappeared, must have been very thin, and the surface remaining is smooth and shining. In general form, so far as can be ascertained from a very imperfect specimen, this shell must have closely resembled the modern Pupæ of the genus *Strophia* of Albers.

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* Modified from Bradley.

The only specimen known is from the Erian (Devonian) plant-beds of St. John, New Brunswick, which, besides affording great numbers of remains of land plants, have produced the only Erian insects as yet known. It was sent to me by Mr. G. F. Matthew, of St. John, along with specimens of fossil plants, several years ago, but I hesitated to describe it, waiting in hope of additional specimens. As these have not occurred, and I have now carefully examined the whole of the material from these beds to which I have been able to obtain access, I venture to name it as probably the oldest known land shell, the beds in which it is found being either middle or upper Erian.

If a land snail, it is larger in size and probably of higher type than any of those known from the Coal-formation. This would not be wonderful, when we consider the greater variety of surface and the high character of the vegetation, which, as I have elsewhere endeavored to show, distinguished the later Erian age in Northeastern America.

Concluding Remarks.

It may be proper to mention here the alleged Pulmonifera of the genus *Palæorbis* described by some German naturalists. These I believe to be worm-tubes of the genus *Spirorbis*, and in fact to be nothing else than the common *S. carbonarius* or *S. pusillus* of the Coal-formation. The history of this error may be stated thus. The eminent paleobotanists Germar, Gœppert and Geinitz have referred the *Spirorbis*, so common in the Coal-measures to the fungi, under the name *Gyromyces*, and in this they have been followed by other naturalists, though as long ago as 1868 I had shown that this little organism is not only a calcareous shell, attached by one side to vegetable matters and shells of mollusks, but that it has the microscopic structure characteristic of modern shells of this type.* More recently Van Beneden, Cænius and Goldenberg, perceiving that the fossil is really a calcareous shell, but apparently unaware of the observations made in this country by myself and Mr. Lesquereux, have held the *Spirorbis* to be a pulmonate mollusk allied to *Planorbis*, and have supposed that its presence on fossil plants is confirmatory of this view, though the shells are attached by a flattened side to these plants, and are also found attached to shells of bivalves of the genus *Naiadites.* Mr. R. Etheridge, Jr., of the Geological Survey of Great Britain, has recently summed up the evidence as to the true nature of these shells, and has revised and added to the species, in a series of articles in the Geological Magazine of London, vol. viii.

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* Acadian Geology, 2d edition, p. 205.

If we exclude the alleged *Palæorbis* above referred to, all the Paleozoic Pulmonifera hitherto found are American. Since, however, in the Carboniferous age, Batrachians, Arachnidans, Insects and Millipedes occur on both continents, it is not unlikely that ere long European species of land snails will be announced. The species hitherto found in Eastern America, are in every way strangely isolated. In the plant-beds of St. John, about 9,000 feet in thickness, and in the Coal-formation of the South Joggins, more than 7,000 feet in thickness, no other Gasteropods occur, nor, I believe, do any occur in the beds holding land snails in Illinois. Nor, as already stated, are any of the aquatic Pulmonifera known in the Paleozoic. Thus, in so far as at present known, these Paleozoic snails are separated not only from any predecessors, if there were any, or successors, but from any contemporary animals allied to them.

It is probable that the land snails of the Erian and Carboniferous were neither numerous nor important members of the faunæ of those periods. Had other species existed in any considerable numbers, there is no reason why they should not have been found in the erect trees, or in those shales which contain land plants. More especially would the discovery of any larger species, had they existed, been likely to have occurred. Further, what we know of the vegetation of the Paleozoic Period would lead us to infer that it did not abound in those succulent and nutritious leaves and fruits which are most congenial to land snails. It is to be observed, however, that we know little as yet of the upland life of the Erian or Carboniferous. The animal life of the drier parts of the low country is indeed as yet very little known; and but for the revelations in this respect of the erect trees in one bed in the Coal-formation of Nova Scotia, our knowledge of the land snails and Millipedes, and also of an eminently terrestrial group of reptiles, the *Microsauria*, would have been much more imperfect than it is. We may hope for still further revelations of this kind, and in the meantime, it would be premature to speculate as to the affinities of our little group of land snails with animals either their contemporaries or belonging to earlier or later formations, except to note the fact of the little change of form or structure in this type of life in that vast interval of time which separates the Erian Period from the present day.

(*From the Canadian Naturalist, Vol. X. No. 2.*)

SECOND [illegible] SURVEY OF PENNSYLVANIA.

NOTE ON A FERN ASSOCIATED WITH PLATEPHEMERA ANTIQUA, Scudder. By J. W. DAWSON, L.L.D., F.R.S., &c.

The oldest remains of insects known to geologists, those of the Erian (Devonian) shales of St. John, New Brunswick, occur in beds rich in plant remains. It was indeed solely by means of the extensive quarrying operations carried on by Messrs. Hartt and Matthew in these beds in search of fossil plants, that the insect remains were discovered. In less thoroughly explored beds, fossils so rare and so obscure could not have been found. It is natural therefore that fossil plants should occur on the same slabs with the insects. On one of these, holding a fragment of the wing of *Platephemera antiqua*, there appears a considerable portion of a frond of *Pecopteris* (*Aspidites*) *serrulata*, Hartt, a common species in these beds, and also a small fragment of a leaf of the still more common *Cordaites Robbii*. It appears that Dr. Geinitz of Dresden saw this specimen in 1866, and not being at that time familiar with the ferns of the Devonian of New Brunswick, very naturally supposed that the frond was that of the closely allied *P. plumosa* of Brongniart, and on this ground he was induced to hint a suspicion that the specimen was of Carboniferous age. Dr. Scudder referred to this opinion of Geinitz in his paper on Devonian insects in the Geological Magazine, Vol. V.; and gave reasons sustaining the Devonian age of both fern and insect. I did not think it necessary to refer publicly to the matter, but took occasion to explain the true state of the case in a private letter to Geinitz; and in my report on the Devonian plants of Canada I quoted Hartt's description in full, and noticed the distinctness of his species from *P. plumosa*.

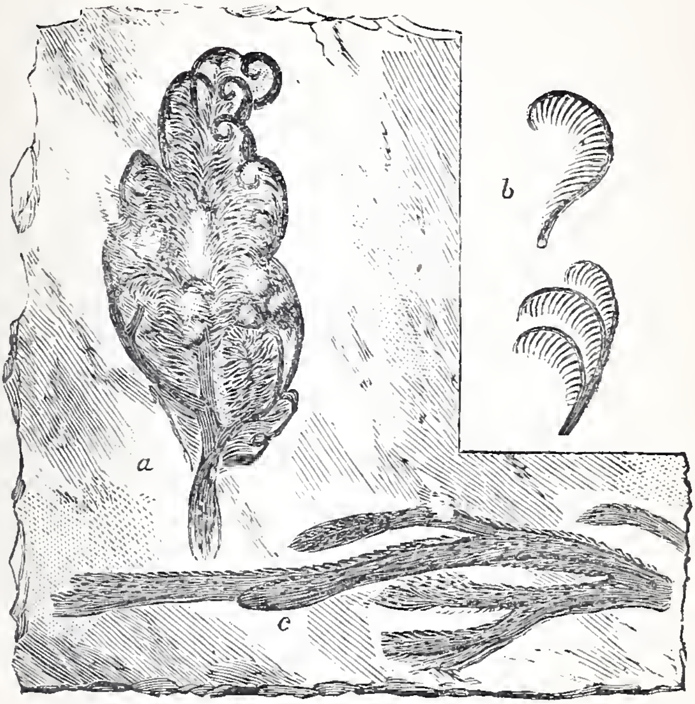
I find, however, that this doubt has been revived by Dr. Hagen in a paper on Devonian insects in the Bulletin of the Museum of Comparative Zoology for the present year (Vol. viii. No. 14). Dr. Hagen does not profess to be an authority in fossil plants, but fortifies his statements by a letter from Mr. Lesquereux, which does not however touch the question at issue, as he does not appear to have compared the specimen or Hartt's species with

P. plumosa; and though he insinuates a doubt as to the validity of some of my Devonian species, even this does not apply, since the species in question was carefully described by the late Prof. Hartt, and accepted by me after study of his material, which included several very considerable portions of well-preserved fronds.

Though doubts and suspicions thus cast on work carefully and exhaustively done, in so far as material exists, should not seriously affect the minds of naturalists, I have thought it desirable to set the matter at rest, as far as possible; and have therefore, through the kindness of Dr. Scudder and the Curator of the Boston Society of Natural History, obtained access to the original specimen, and would now state the actual facts.

The fern on the specimen in question (No. 8496 of the Boston Society's collection) is undoubtedly *Pecopteris serrulata* of Hartt, and exhibits in a tolerable state of preservation six secondary pinnae of one side of a primary pinna of the species. To a hasty observer, supposing the specimen to be a piece of Carboniferous shale, it would be natural to refer the fern to *P. plumosa* of Brongniart or to *Aspidites silesiacus* of Goeppert, which it perhaps more closely resembles; and since its fructification is still unknown, it may quite as likely belong to the group or sub-genus *Aspidites* in which Goeppert and Schimper place *P. silesiaca*, as to that of *Cyathites* in which Schimper places *P. plumosa*.

The distinctive characters indicated by Hartt are principally the form and insertion of the pinnæ, the slender crenulate revolute, lanceolate pinnules, and the simple veinlets. Perhaps the most obvious characteristic is the peculiarly elongated acuminate points of the primary and secondary pinnæ, in which this species seems to differ from all its near allies. In the specimen in question, though only a portion of one side of a primary pinna is seen, and its characteristic elongate termination is absent, yet one of the secondary pinnæ shows this character very well, and the simple veins and crenate revolute margins may be made out with a lens in a good light. I do not think that any palæobotanist, in view of these characters, would decide to identify this fern with *P. plumosa*, unless indeed he were of opinion that the whole group to which that species belongs should constitute one broad specific type extending from the Devonian to the Permian, a view to which I should have no objection, provided sufficient connecting links can be found.



Ptilophyton Thomsoni.

(*a*) Impression of plant in vernation.

(*b*) Branches conjecturally restored.

(*c*) Branches of *Lycopodites Milleri.*

In this cut the parts of the fossil are given more coarsely and distinctly than in the original.

SECOND GEOLOGICAL SURVEY
OF
PENNSYLVANIA.

It is farther to be observed that this fern occurs with a group of species which I have shown to be distinct not only from those of the Coal Formation but from those of the Millstone Grit and those of the Lower Carboniferous Coal-measures or Horton series (sub-Carboniferous of some American geologists), which sub-floras are well developed in the Acadian provinces, and overlie stratigraphically the beds holding the fern which is the subject of this note and its associated fossils.

I may add here Hartt's description of the plant and my note on it, from my Report of 1870 :—

"PECOPTERIS (ASPIDITES ?) SERRULATA, Hartt.—(Pl. XVIII, Figs. 207 to 209.)—Acad. Geol. p. 553, Fig. 92.—M.D., St. John, New Brunswick."

Tripinnate; pinna short, alternate, close or open, lanceolate, very oblique, situated on a rather slender, rounded, sub-flexuose rachis; pinnules small, linear lanceolate, crenulate, revolute, moderately acute, oblique, sessile, decurrent, widest at the base, open, separated from one another by a space equal to the width of a pinnule, slightly arched towards the point of pinna; longest at base of pinna, decreasing thence gradually to the apex; terminal pinnule elongated. Median nerve entering the pinnule very obliquely, flexuous, running to the apex. Nervules very few, oblique, simple, and somewhat rarely forking at the margin."

"Numerous additional specimens of this species confirm Prof. Hartt's determination of its distinctness from *P. plumosa*, Brongt. It perhaps more strongly resembles Goeppert's *P. Silesiaca*; but this last has broader and more closely arranged pinnules decurrent on the petiole. It may be taken as a Devonian representative of the delicate Pecopterids of which the species above named are Carboniferous types. Mr. Hartt's specimens enable me to represent its habit of growth. Schimper quotes under this name a Carboniferous species of Lesquereux. But Lesquereux's species is *Alethopteris serrula*." (This was subsequently corrected by Schimper in the Supplement to his Palæontologie Vegetale.)

[From the Proceedings of the American Association for the Advancement of Science,
Buffalo Meeting, August, 1876.]

NEW FACTS RELATING TO EOZOON CANADENSE. By J. W. DAWSON, of Montreal, Canada.

AT the last meeting of this Association, I had the pleasure of exhibiting some specimens of *Eozoon Canadense*, and of giving some oral explanations as to its nature and mode of occurrence. I now ask permission to mention a few additional facts which have been made known since the meeting at Detroit, and which still further contribute to our knowledge of the most ancient known fossil.

(1.) I would first beg leave to direct attention to the very interesting series of specimens now on exhibition in Philadelphia, in the collection of the Canadian Geological Survey; and which give a rare opportunity to study the various aspects of the fossil. In connection with Eozoon, I would also mention the remarkable mass of Graphite from Buckingham on the Ottawa, exhibited by the Dominion Plumbago Company of Canada. This mass is from one of the great beds of that mineral occurring in the Lower Laurentian, on a horizon not remote from that of Eozoon, and which in my judgment are really Laurentian coals, representing the vegetation of that period, as yet altogether unknown to us in its forms and structures.

(2.) A very interesting specimen, found last autumn by Messrs. Richardson and Weston, at Petite Nation, has enabled me to delineate, in a recent paper, the inverted conical form of a perfect small specimen of Eozoon, and also to show that the acervuline chambers on its upper surface are precisely similar to those small aggregations of spherical chambers resembling *Globigerinæ*, and to which I have given the name *Archæospherinæ;* so that these may not improbably be loose chambers or germs of Eozoon.

(3.) Mr. W. J. Morris of Perth, Ontario, has in the past summer found abundant specimens *in situ* of Eozoon mineralized with Loganite, in the original locality at Burgess. These specimens show that the Burgess variety is on the whole thicker and more continuous in its sarcode chambers, and less developed as to the separating walls than the Grenville and Petite Nation specimens. These new specimens from Burgess have also enabled me for the first time to detect in their dolomitised walls traces of the canal system, into which, however, the Loganite does not penetrate. In some in which the dolomite is mixed with calcite, there is also an extremely minute granular structure, which I believe to indicate an originally porous character of the cell-wall, of which only obscure indications exist in other specimens.

(4.) Mr. G. F. Matthew has sent to me from the Laurentian of Lily Lake, near St. John, New Brunswick, specimens of a dolomitic limestone containing fragments of the skeleton of Eozoon, showing the canal system. This is the first recognition of this fossil in the Laurentian of New Brunswick. A notice of the fact has appeared or will shortly appear in "Silliman's Journal."

(5.) Recent explorations by Mr. Vennor of the Geological Survey have thrown further light on the precise geological horizon of Eozoon in the great Laurentian system. In Sir William Logan's original sections on the East side of the Ottawa, the lowest rock represented is a great thickness of orthoclase gneiss, corresponding probably to the fundamental or Bogian gneiss of the Scandinavian and Bavarian geologists. Above this is a very thick limestone, that of Trembling Lake, which has afforded no fossils. Next is another vast thickness of gneissic beds. Then comes a second limestone, also non-fossiliferous as yet, that of Green Lake. Then another gneissic series and a third limestone, that of Grenville, which is the special resting place of Eozoon, and is also associated with beds rich in graphite and in calcic phosphate. Still higher is a fourth limestone, and then the Upper Laurentian. Mr. Vennor's observations relate to a region about eighty miles distant, on the west side of the Ottawa and remarkable for its rich deposits of apatite and graphite, though affording Eozoon only in a few places, and in these not precisely in the same state of mineralization as at Petite Nation and Grenville. In this region Mr. Vennor has worked out a series corresponding in its main features with that ascertained by Logan, and it now appears that in both series Eozoon is apparently confined to one horizon, and that in this it is associated with the more important deposits of graphite and apatite. It is true that in the districts explored by Mr. Vennor there are some groups of strata of uncertain age, and which may be upper Laurentian or even Huronian; but the main accordance above stated seems to be certain. It would thus appear that Eozoon and those deposits of graphite and apatite which are probably of organic origin, are characteristic of one great zone of the Lower Laurentian.

(6.) The abundant phosphates occurring in the Lower Laurentian, and as already stated in irregularly stratified beds, and associated with graphite and Eozoon, naturally raise the question whether they are of organic accumulation. The apatite of the Lower Laurentian has indeed as yet afforded no organic structure. Some light may however be thrown on its origin by the analogy of later deposits of similar character; and I have endeavored, in a paper recently read before the Geological Society of London, to show that the calcic phosphate contained in the Cambrian and Silurian rocks of Canada presents in its mode of occurrence points of similarity to that of the Laurentian; while the prevalence of low forms of life, as *Lingulæ*, *Trilobites* and *Hyolithes*, having much calcic phosphate in their skeletons, in the Primordial seas, and the consequent accumulation of beds rich in phosphatic concretions and coprolites, points to the possibility of similar conditions in the earlier Laurentian. I may also here refer, as corroborative of this view, to the recently published researches of Hicks and others on the Silurian Phosphates of Wales.

(7.) The objections to the animal nature of Eozoon recently promulgated by Otto Hahn, and which have been answered in detail by Dr. Carpenter and myself, have directed attention anew to the geological relations of serpentine; and though I must protest against the idea prevailing in some quarters, that there is any necessary connection between this mineral and Eozoon, yet as serpentine exists in connection with many specimens of this fossil, it is time that geologists were warned against the extravagant ideas of pseudomorphism which have been promulgated in connection with it. I have, therefore, been engaged in the present summer in reëxamining large series of specimens of serpentines associated with organic remains, and have visited some of the Canadian localities of such serpentines, and have studied their geological relations. I hope to show, when these researches are complete, that microscopical and palæontological evidence completely vindicates the theory of aqueous deposition of serpentine as maintained by Dr. T. Sterry Hunt, and shows that this mineral, like glauconite and similar silicates, may fill the pores and cavities of fossils, without in any way destroying their forms or structures. I have examples of Silurian corals and other fossils mineralized with true serpentine, precisely like Eozoon in the Laurentian. Further it can be shown that the Lower Silurian serpentines of Canada, alike in their interstratification with fossiliferous limestones, and in their passage into limestone, dolomite and even red slates, conform in a striking manner to the known laws of deposition of hydrous silicates in the modern oceans. Whatever opinions may be held as to the metamorphic origin of certain serpentines, or as to the mode of formation of serpentine veins, the facts I already possess are amply sufficient to show that such theories have no application to the ordinary serpentines found in beds associated with fossiliferous rocks.

(8.) I may add that I hold Gümbel's elaborate exposition of the foraminiferal nature of *Receptaculites*, in the Transactions of the Royal Bavarian Academy, and the announcement by Prof. Karl Moebius of a recent sessile Foraminifer from the Mauritius, not very remote from Eozoon in its general mode of growth, to be important contributions towards the history of this oldest fossil; whose investigation, as will be seen from the above notes, is by no means fully worked out.

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SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA

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